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A methodology for technology characteristics and evaluation for naval ships

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A METHODOLOGY FOR TECHNOLOGY CHARACTERIZATION AND EVALUATION FOR NAVAL SHIPS

by

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ABSTRACT

A rational method for evaluating hull, mechanical, and electrical technologies for future ship designs is presented. Requirements are established for the management and coordination of technology information. A format is proposed for the characterization of emerging technologies. The basic steps necessary to establish a technology assessment baseline ship are presented. In addition, a process is developed for conducting impact evaluation when performance is held constant. A case study for a frigate is conducted to validate the proposed methodology. The methodology will assist ship designers and research and development managers in deciding which technologies should be funded so they may be incorporated in a future ship design.

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SYMBOLS AND ABBREVIATIONS

AAW	Anti-Air Warfare
Amphib	Amphibious
ASSET	Advanced Surface Ship Evaluation Tool
ASU	Approved for Service Use
ASW	Anti-Submarine Warfare
B	Beam at DWL
CER	Cost Estimating Relationship
COGAS	Combined Gas Turbine and Steam Plant
CONFORM	NAVSEA Program for Continuing Concept Formulation
C_P	Prismatic Coefficient
CPS	Collective Protection System
CR	Contrarotating Propeller
CRP	Controllable, Reversible Pitch Propeller
C_x	Maximum Section Coefficient
D	Depth to Main Deck at Midships
DDS	Design Data Sheet
DTNSRDC	David W. Taylor Naval Ship Research and Development Center
DWL	Design Waterline
FBD_0	Freeboard at Station Zero
FP	Fixed Pitch Propeller or Forward Perpendicular
GM_T	Metacentric Height
GT	Gas Turbine
HM&E	Hull, Mechanical, and Electrical
HSLA	High Strength Low Alloy Steel

SYMBOLS AND ABBREVIATIONS (CONTINUED)

HTS	High Tensile Strength Steel
HY80	High Yield Strength Steel (80 KSI)
IOC	Initial Operational Capability
IR	Infrared
IRGT	Intercooled/Regenerative Gas Turbine
KG	Distance from the Keel to the Center of Gravity
K_N	ASSET Cost Factors
KSF	Keel Shock Factor
KSI	1000 pounds per square inch
KT	Knot
LBP	Length Between Perpendiculars
LT	Long Ton (2240 lbs)
LV II	Level II Fragmentation Protection (magazines, vital spaces, cable ways, vital topside equip)
MONOSC	Monohull Surface Combatant version of ASSET
MPL	Model Parameter List
NAVSEA	The Naval Sea Systems Command
NBC	Nuclear, Biological, and Chemical
NM	Nautical Mile
OPNAV	Office of the Chief of Naval Operations
Ops	Operations
O&S Costs	Operating and Support Costs
PC_{DESIGN}	Propulsive Coefficient at Design Condition (8[illegible] Installed Power)
PC_E	Propulsive Coefficient at Endurance Speed

SYMBOLS AND ABBREVIATIONS (CONTINUED)

PDSS	Propulsion Derived Ship Service
$\hat{R}$	Bales' Seakeeping Rank Factor
R&D	Research and Development
RCS	Radar Cross Section
SFC_{DESIGN}	Specific Fuel Consuption at Design Condition (80% Installed Power)
SFC_E	Specific Fuel Consumption at Endurance Speed
SHP_E	Shaft Horsepower at Endurance Speed
SHP_I	Installed Shaft Horsepower
SSCS	Ship Space Classification System
SSES	Ship System Engineering Standards
SSG	Ship Service Generator
SSGN	Cruise Missile Nuclear Attack Submarine
SUW	Surface Warfare
SWATH	Small Waterplane Area Twin Hull Ship
SWBS	Ship Work Breakdown Structure
T	Draft to DWL
UNREP	Underway Replenishment
V_E	Endurance Speed
V_S	Sustained Speed (Speed at 80% Installed Power)
$\forall_T$	Total Ship Volume
W_P	Payload Weight
Δ	Displacement
Δ/L	Displacement Length Ratio

CHAPTER 1

INTRODUCTION

1.1 Background

The introduction of new hull, mechanical, and electrical (HM&E) technology into the fleet over the last several decades has generally been accomplished by justifying the risk in terms of savings in acquisition and life cycle cost dollars. This has resulted in an approach to technology evaluation in which the performance is normalized and impact is assessed in terms of ship size, configuration, cost, and risk.

Candidate technologies for new ship designs are normally identified by surveys conducted during early stage design. The trend has been to concentrate on areas with perceived high cost or performance impact. In practice, candidate technologies have been identified in two ways [1].

(1) The "technology-push" mode, in which the advocate proposes that a particular innovation be studied. Examples include numerous propulsion and auxiliary systems.

(2) The more methodical approach of reviewing research and development (R&D) areas and design sensitivities.

The design team evaluates each of the proposed technologies and advocates funding for the most promising in terms of ship impact, cost, or performance. However, unless the system is developed to a point that it is ready for technical or operational evaluation, it is very difficult to

incorporate the system into the lead ship. So one must advocate the development of these systems prior to the start of a design.

The approach currently taken in the continuing concept formulation (CONFORM) studies is to identify new systems and associated risk very early in the design process. This is a step in the right direction. However, there is a strong need to improve the interrelationship between the exploratory development of new systems and the development of new ship concepts.

The intent of this thesis is to provide a rational thought process for assessing HM&E technologies for future ship designs. The major segments of technology assessment addressed by this thesis include:

(1) how to properly characterize HM&E technologies for impact analysis,

(2) how to establish and maintain a continuously developing series of baseline ships,

(3) how to conduct technology impact evaluations when performance is held constant, and

(4) what assessment tools need to be developed.

1.2 Time Frame

New technology may be introduced into a ship design at various stages of development. A technology may be backfitted into an existing ship, incorporated in an ongoing acquisition program, or selected for inclusion into a future ship design. The ground rules for accomplishing each of these tasks vary with the degree of constraint.

Backfitting a technology into an existing ship represents the most constrained situation. The process may range from an extensive conversion to minor ship alterations. The designer must work within available growth margins and/or remove equipment presently on the ship. Backfitting is the least desirable method for taking advantage of new HM&E technology. It is usually done to correct severe problems, to provide an immediate response to a new threat, or in a single application to test out a new technology.

On the other end of the spectrum is the decision to develop an emerging technology for a future ship design. This decision should be made prior to entering conceptual design, about 20 years prior to delivery of the lead ship. The design is still highly flexible and the full benefit of including the technology may be investigated.

Incorporating a technology in an ongoing ship acquisition program represents a situation somewhere between backfit and pre-design. The ship is well defined so only minor changes

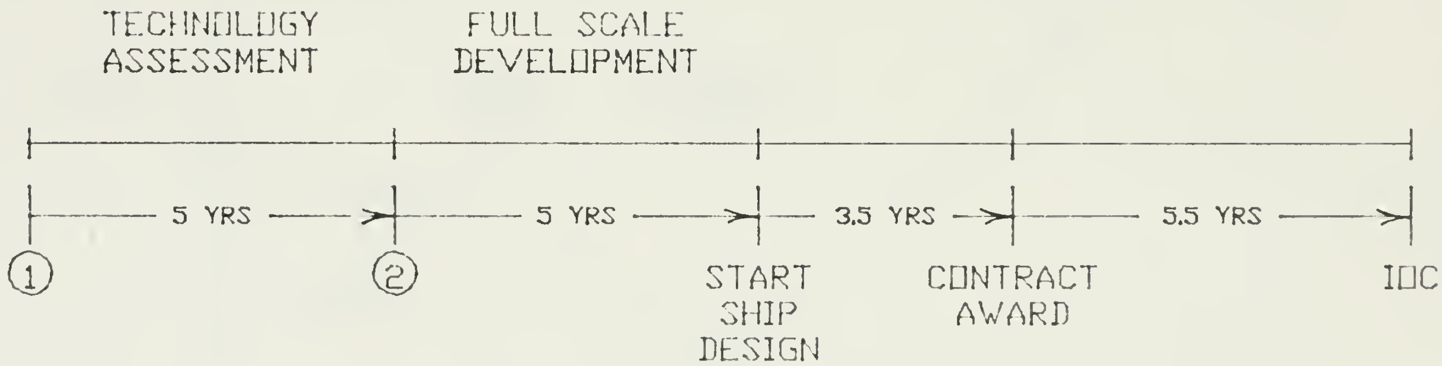
may occur in the design or time schedules, and cost will be severely impacted.

This study addresses the pre-design time frame because it has the greatest potential for improvements in cost effectiveness. In addition, there presently exists no generally accepted methodology for assessing technologies.

Figure 1 shows the relationship between technology development and the formal ship design process. Initial technology development and assessment should occur 10 years prior to the start of the formal design period. This will enable identification of critical areas early in the process so that efforts can be made to better define unknowns and correct deficiencies. Full-scale development of the most promising technologies must begin at least five years prior to the start of the design. If this time period is not allowed, decision makers will not risk incorporating them in the design. The proposed methodology is intended to assist with the initial commitment and the decision to enter full scale development.

Figure 2 shows the decreasing cost savings leverage as the ship design progresses. Most of the major decisions effecting cost are made early in the process of determing performance requirements and selecting subsystems. Hence, it is important to have a rational evaluation process for the selection of competing subsystem technology.

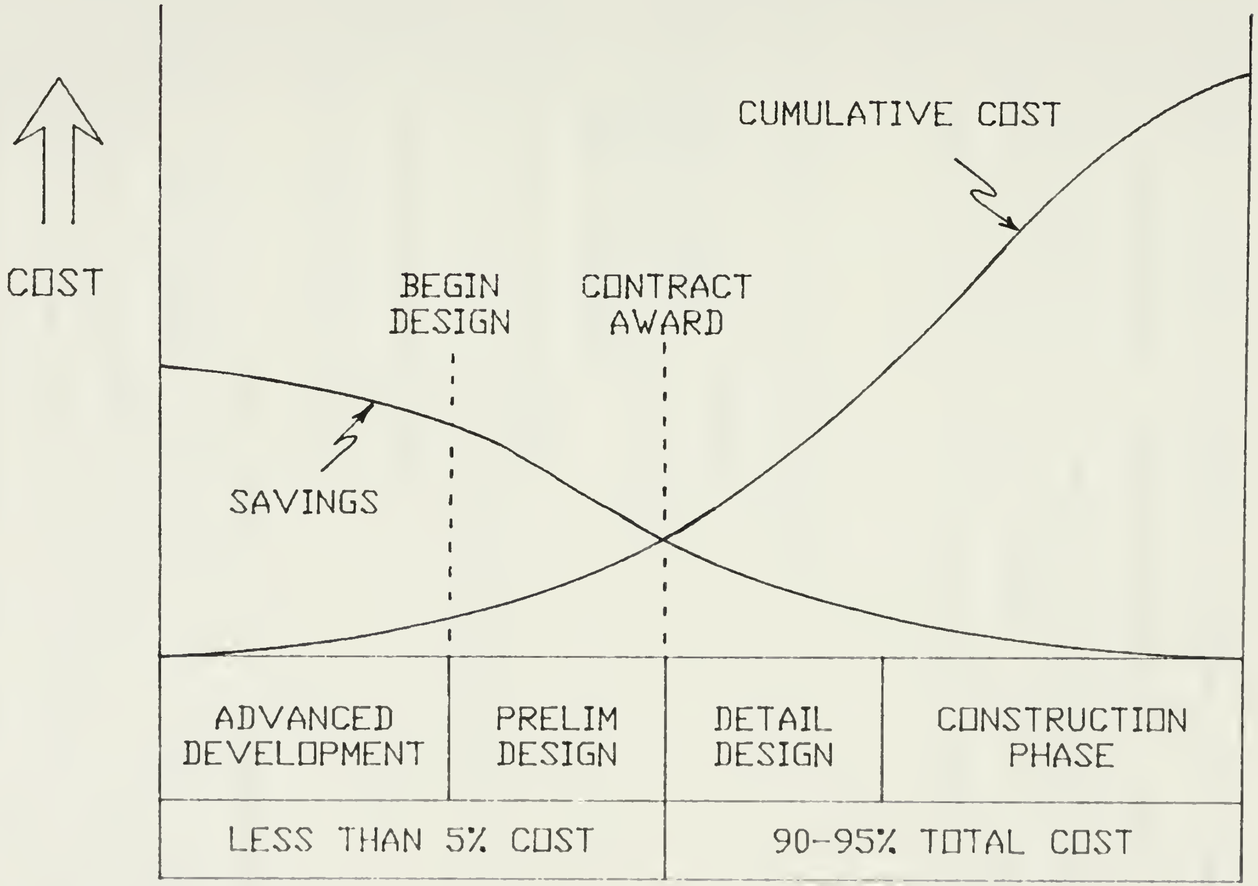
Figure 1. TECHNOLOGY DEVELOPMENT FOR NAVAL SHIP PROGRAMS



1 TECHNOLOGY ASSESSMENT AND INTIAL COMMITMENT DECISION

2 FULL SCALE DEVELOPMENT DECISION

Figure 2. DECREASING COST SAVINGS LEVERAGE AS PROGRAM PROGRESSES



CHAPTER 2

METHODOLOGY

2.1 Introduction

The proposed rational thought process for assessing alternate HM&E technologies was developed to assist ship designers and R&D managers in selecting which technologies should be funded so they may be included in a future ship design. The steps involved in the proposed methodology are outlined below.

(1) Characterize the technologies

(2) Evaluate the technologies:
  (a) Ship impact
  (b) Performance assessment
  (c) Cost estimate
  (d) Risk assessment

(3) Catalog the technologies

(4) Perform integrated technology evaluations

(5) Make committment decision

(6) Create development plan

The initial step is to characterize the technologies in order to obtain the necessary data for the impact analysis. Once sufficient data is available, the impact of incorporating the individual technologies needs to be evaluated in terms of ship size, configuration, performance, and cost. The results of these evaluations can be catalogued to assist ship designers who are searching for emerging technologies. The

designer can then select synergistic combinations of the most promising technologies and perform integrated technology evaluations. Those offering the most benefit in terms of mission effectiveness, affordable cost, and acceptable level of risk should be funded for development.

Once the commitment decision has been made, the final step is to create a plan for development and implementation of the technology.

2.2 Technology Information Management

The following is required for the management and coordination of technology information [1].

(1) Establishment of a central clearing-house for technologies applicable to naval ships

(2) Characterization of data for emerging technologies in a format compatable with early stage design tools

(3) The preparation and maintenance of a new technology data base

(4) The preparation of a new technology catalog on a routine basis for use by the Office of the Chief of Naval Operations (OPNAV) and the design community in preparing mission and design requirements

(5) Implementation of feedback mechanisms for influencing R&D resource allocations

The establishment of a central clearing-house will consolidate in one place, and in a single system, those aspects of exploratory and advanced development which deal with: technology characterization, technology assessment, and R&D needs. Currently these activities are handled by separate organizations giving rise to considerable confusion about whom to approach with a new technology for naval application.

The primary purpose of the technology characterization is to provide data necessary for ship impact analysis. However, if formatted correctly, the characterization can also serve additional functions. It can provide an initial screen to determine if the technology is applicable to naval ships. It can give an indication of how well the technology is

understood. It can also tell whether additional R&D is required before an impact study can be conducted. In general, unless the technology is obviously not applicable to naval ships, enough funds should be appropriated to perform an impact analysis. A proposed format for the characterization sheet is presented in Figure 3.

The preparation and maintenance of a new technology database is a crucial item for the effective management of technology information. It requires identification and integration of all necessary technical data from any available source. In defining what data will be stored, it will be important to consider what data is needed for impact analysis, what information is desired for the catalog of technology evaluations, and what type of relations among the data are desired.

The database should be able to identify possible synergistic combinations among the various technologies. Identification of synergistic relations is important because of the additional gains that can result from the integration of complementary technologies. The biological definition of a synergism is, "The action of two or more substances, organs, or organisms to achieve an effect of which each is individually incapable". The system engineering adaptation is, "The whole is greater than the sum of the parts". An example of a synergistic relationship in ship design is the combination of a technology which lowers the vertical center

Figure 3. RECOMMENDED FORMAT FOR A TECHNOLOGY CHARACTERIZATION SHEET

Name of Technology:

Point of Contact/References:

Brief Description:

Short narrative describing the technology to include a general statement on how the technology improves the performance of the ship and/or allows a size/cost reduction. Provide sketch of concept compared to current approach.

Categorization: Circle appropriate items.

1. Direct Influence on Ship Performance

   a. Combat Capability (specify warfare area)

   b. Survivability (signature, protection)

   c. Mobility (sustained speed, range, maneuveribility)

   d. Seakeeping

   d. Operability (reliability, maintainability, availability, ease of operation)

2. Functional Area Affected by Technology

   a. Combat System

   b. Containment

   c. Main Propulsion

   d. Electrical

   e. Auxiliary

   f. Outfit/Human Support

TECHNOLOGY CHARACTERIZATION SHEET (CONTINUED)

3. Ship Impact

   a. Weight: Hull Superstructure Topside

   b. Space: Location - Hull, Superstructure
      Type - Deck Area, Large Object, Tankage

   c. Manning

   d. Energy

4. Applicable Ship Size/Type

   a. Size: CV CG DD FF PF

   b. Type: Monohull SWATH SES HYDROFOIL ACV

5. Cost

   a. Will the technology provide a direct reduction in cost ? y / n

   b. Type of cost: Acquisition, Operating and Support

Development Status:

What is the status of development? What remains to be done?

Technical Information:

Pertinent technical information to conduct ship impact assessment. Need to have formatted enclosures that can be provided for each major technology category (material, main engine, generator, etc.).

of gravity (KG), and one that allows a reduction in volume and beam. The integration of the two technologies results in a smaller ship with superior powering characteristics. The improved powering produces an increase in sustained speed and endurance, or a reduction in installed power. The basic guideline is to look for combinations which enhance attributes and offset undesirable characteristics. The possibilities are limited only by the imagination of the designer.

One of the primary goals of the proposed technology assessment program is to improve communication between the ship operator, designer, and R&D manager. Recommendations to accomplish this include the publication of a new technology catalog to provide a greater awareness to the ship design community of the status and results of Navy ship-related research and development programs, and development of a feedback mechanism to influence resource allocations.

2.3 Baseline Ship Development

The baseline ship chosen for impact analysis can influence which technologies are selected for development. Therefore, it is important to discuss the attributes of a good "technology assessment" baseline. Essentially, the baseline must be a "tight" design balanced in space, weight, stability, and energy. The design should possess no excess space, weight, stability, or powering beyond that required by standard design margins. In this way, the full impact of the technology may be assessed without concealing the results in excessive margins or design flexibility.

When evaluating technologies for a future design, a reasonable projection of what technologies will be available and notionally acceptable to the decision makers must be made. Baselines are thus dependent on what stage of the design process we are interested in. A rational approach is to develop a set of baselines and store them in an integrated database. They should be well-balanced designs created by experienced ship designers to cover the various time frames and ship types. The following categories are appropriate.

(1) Fleet Asset - Ship currently in the fleet

(2) New Acquisition - Initial Operational Capability (IOC) 10 years in the future

(3) Technology Assessment - IOC 20 years in the future

The fleet asset baseline is the ship currently in the fleet that is fulfilling the prescribed mission requirement. These baselines can be used to assess the approximate impact of introducing a new technology into fleet units, and serve as a basis for comparison with conceptual baselines for the future. The new acquisition baseline is a feasibility level design, with an IOC ten years in the future, which incorporates all current design practices and standards, and new design margins. Technology innovations determined to be mission and cost effective and projected to be approved for service use (ASU) by IOC minus eight years should be incorporated in the baseline. These "acquistion baselines" could be ready, at any time, to move directly into the acquisition cycle. They would therefore incorporate only mature, low risk technologies. These baselines could be used for answering the many "what if" questions that continually arise. The technology assessment baselines would be conceptual/feasibility level designs for IOCs 10 to 20 years in the future. These "technology assessment" baselines could serve as sounding boards for proposed technology and design innovations.

For example an ASW frigate baseline data bank would include FF-1052 as the current fleet asset. The acquisition baseline would probably be a seakeeping monohull with mechanical drive, while the technology assessment baseline might include a SWATH design with electric drive, an advanced

monohull, and an SES variant. The data bank should be updated each year and the baselines presented as new "spring styles". The requirement to maintain these baselines could serve as the principal task for CONFORM.

As previously stated, the development of a proper baseline is essential for determing the true impact of the technology being assessed. Therefore, specific guidance will be given for establishing technology assessment baselines with IOCs 20 years in the future. The proposed process improves and formalizes a process that NAVSEA already uses on an ad hoc basis. General advice is to establish a comfortable baseline. This is important because if the baseline is too extreme the results of the impact analysis may be invalidated. Hence, one should avoid controversial technology which might jeopardize the program. On the other hand, a baseline which is overly conservative would result in an overly large ship that is unaffordable. A technology assessment baseline needs to be developed to a sufficient level of detail to enable a reasonably accurate impact analysis to be accomplished. In order to achieve plausible impact analysis results, the designer needs to have information concerning ship performance, basic ship characteristics (size and configuration), manning, margins, cost, and risk. This requires a level of detail somewhere between a feasibility study and conceptual design.

The basic steps necessary to establish a nominal technology assessment baseline are outlined below. If the rules are difficult to follow, deviate in a manner that an "intelligent designer" would perceive as most rational.

(1) Performance Requirements

Develop attainable performance requirements based on the statement of need and mission analysis. Ideally, this would be accomplished in cooperation with OPNAV. The performance factors should be stated as threshold values that must be met, and goals which are highly desired to be met. The parameters to be addressed are given in Table 1.

(2) Subsystem Selection

The basic intent is to choose subsystems that will enable the ship system to meet the performance requirements and to be acceptable to decision makers. Use "new standards" such as a protected aluminum or steel superstructure, Collective Protection System (CPS), Ship System Engineering Standards (SSES), etc.. It is recommended that the designer sketch several rough conceptual alternatives and choose the most plausible one prior to engaging in the formal selection process. Table 2 lists the subsystems that need to be selected.

Table 1. PERFORMANCE REQUIREMENTS

1. Combat Capability
   - Specify combat capability in each warfare area (AAW, ASW, SUW, Strike, Mine, Amphib)

2. Survivability
   - signatures (IR, RCS, noise, visual, magnetic)
   - protection (blast, frag, NBC, shock)

3. Mobility
   - speed
   - range
   - stores period
   - maneuverability

4. Seakeeping
   - motion limitations (Flight Ops, crew, equip)
   - deck wetness
   - slamming

5. Operability
   - reliability
   - maintainability
   - availability

6. Manning
   - unit commander
   - crew size (if constrained)
   - aviation department size

7. Planned use
   - environment
   - operating profile

Table 2. SUBSYSTEM SELECTION

1. Combat System
   - Command & Control
   - Exterior Comms
   - Sensors
   - Armament
   - Aviation

2. Containment
   - Hull Form
   - Superstructure
   - Materials

3. Propulsion Plant
   - Main Engines
   - Secondary Engines
   - Transmission
   - Propulsor

4. Electric Plant
   - Prime Movers
   - Generators
   - Frequency Conversion

5. Auxiliaries
   - Type (Electric, Steam)
   - Ventilation System
   - Prairie Masker
   - Rudder
   - Fins
   - UNREP Gear
   - Ballast

6. Outfit/Human Support
   - Habitability (plush, modern, austere)
   - Stowage (Vidmar, racks & bins)

(3) Balance the Design

System integrate the subsystems to obtain a balanced design utilizing standard design practices and criteria appropriate for a feasibility study. If the design can not be balanced in weight, stability, space, and energy, subsystem selection may not have been proper. The recommended design margins for monohull surface combatants are given in Table 3. With the exception of zero space margin, the recommended design margins are consistent with CONFORM feasibility design margins given in reference [14]. CONFORM uses a 5% arrrangeable deck area and tankage margin. These margins cloud an impact analysis by adding a bias, and hence, it is recommended that a zero space margin be used for the purpose of technology assessments.

Recommended design margins for advanced marine vehicles are similiar to monohull designs except for some differences in weight, KG, and powering. SWATH, hydrofoil, and surface effect ships are more sensitive to weight changes but less sensitive to KG changes; hence they should possess 15% weight and 10% KG acquisition margins. The service life weight margin for these modern ships is taken as 10% of the equivalent monohull full load displacement. The equivalent monohull is defined as the monohull designed to the same performance

Table 3. RECOMMENDED TECHNOLOGY ASSESSMENT DESIGN MARGINS FOR A MONOHULL SURFACE COMBATANT

	ACQUISITION	SERVICE LIFE
Weight (1)	12.5% (Groups 1-7)	10%
KG	12.5% (KG of Gr 1-7)	1.0 FT
Space	0 (No excess volume)	0
Electrical (2) (Ship Service)	20%	20% (Prop excluded)
Propulsion (3) Power	10% (Total EHP) prior to prelim body plan 8% prior to self-propelled model tests	
Accommodations	Accom = 1.1 x ship manning at delivery	
Strength	2.24 KSI of marginal stress at delivery (Max primary stress for hull material)	

Notes:

(1) The service life weight margin applies only to naval architectural limits of the ship (reserve buoyancy, stability, structures) not to the final design weight.

(2) In sizing the electric plant, the calculated maximum electric load plus these design margins shall be met with one generator out of service. The remaining generators shall not be loaded in excess of 90%. Note that the service life margin is not applied to SWBS group 200 which would be expected to remain stable over the life of the ship.

(3) Performance requirements (V_B, endurance) are met at delivery full load displacement.

requirements SWATH ships should be designed with a service life KG margin of 2.8 FT because of the relatively high vertical location of the box and superstructure (potential growth location). Air cushion vehicles, surface effect ships, hydrofoils, and planing craft are required to have a 25% thrust margin over drag at hump speed in the design sea state at delivered full load displacement. Exceptions to these margin requirements should be permitted only for unique cases.

USN design standards and practices are officially promulgated by Design Data Sheets (DDS). They establish step-by-step procedures for performing calculations at various levels of design. The Design Data Sheets listed in Table 4 are considered applicable for the development of a technology assessment baseline. In some cases, it may not be necessary to carry out the full set of calculations prescribed by the Design Data Sheet. For example, if the design is a conventional monohull, it is reasonable to assume that the ship possesses adequate stability if $GM_T/B - 0.1$. Similarly, bending moments for structural design may be based on regression analysis instead of the more detailed static calculations required by DDS 100-6 as long as the design does not deviate significantly from the ships used for the regression analysis.

Table 4. DESIGN DATA SHEETS APPLICABLE TO DEVELOPMENT OF A TECHNOLOGY ASSESSMENT BASELINE

DDS 051-1	Prediction of Smooth Water Powering Performance for Surface Displacement Ships
DDS 079-1	Stability and Buoyancy of U.S. Naval Surface Ships
DDS 079-2	Minimum Required Freeboard for U.S. Naval Surface Ships
DDS 100-6	Longitudinal Strength Calculation
DDS 200-1	Calculation of Surface Ship Endurance Fuel Requirements
DDS 310-1	Electrical System Load and Power Analysis for Surface Ships

(4) Design Summary and Analysis

Once the design has been balanced in weight, stability, space, and energy, it is important to step back and scrutinize the design. The data listed in Table 5 is considered sufficient for design review. As a minimum, the following items should be examined in order to ensure the design is plausible.

(a) Aesthetics - Does the design look reasonable? Is it similiar to what we are used to seeing, or is it vastly different ?

(b) Gross Characteristics - Parameters within normal variations ?

(c) Powering - Is sustained speed sufficient ? Is the propulsive coefficient reasonable ? Endurance power adequate ?

(d) Ship Service - Do the average and peak electrical loads follow current trends ?

(e) Weight - Are the percentages allocated as expected ?

(f) Stability - Is the metacentric height reasonable ?

(g) Arrangeability - Is the available space sufficient ? Enough detail to ensure that the large objects fit and that there is adequate topside deck area.

(h) Margins - Is the design well-balanced with adequate, but not excessive margins ?

If the design appears plausible, then it should be analyzed to obtain the necessary data for technology assessments and to ensure it meets all the performance requirements. If the design does not measure up, then new subsystems will probably need to be selected.

Table 5. RECOMMENDED BASELINE DESIGN SUMMARY

1. Gross Characteristics

Length between perpendiculars, LBP
Beam, on design waterline, B
Draft to design waterline, T
Depth to main deck at midship, D
Freeboard at station zero, FBD_o
Full load displacement, Δ
Payload weight, W_P
Total ship volume, $\forall_T$
Metacentric height, GM_T
Prismatic coefficient, C_P
Maximum section coefficient, C_x
Payload fraction, W_P/Δ
Displacement to length ratio, $\frac{\Delta}{L}$
Volumetric density, $\forall_T/\Delta$
Length to beam ratio, LBP/B
Beam to draft ratio, B/T
Length to depth ratio, LBP/D
Metacentric ht to beam ratio, GM_T/B
Estimated roll period

2. Powering

Sustained Speed, V_S
Endurance Speed, V_E
Range
Fuel Weight
Endurance power, SHP_E
Propulsive coefficient at endurance, PC_E
Specific fuel consumption at endurance, SFC_E
Propeller diameter
Maximum propeller RPM

3. Ship Service

Propulsion plant electrical load
Average 24 hr electrical load
Maximum electrical load

4. Weight Breakdown

   SWBS groups 1-7
   Acquisition margin
   Lightship weight
   Loads
   Full load weight

5. Volume Breakdown

   Hull Volume
   Deckhouse Volume
   Volume Budget (%)
      Mission
      Human Support
      Ship Support
      Ship Mobility
      Unassigned

6. Manning

   Ship Manning
      Officer
      CPO
      Enlisted
   Accommodations

7. Margins

   Weight
   KG
   Space
   Electrical
   Propulsion Power
   Accommodations
   Strength

The analysis data listed in Table 6 is considered sufficient for performing technology assessments. The actual amount of data required will depend on the tradeoff being conducted. Table 6 is a wish list since information on signatures, seakeeping, reliability, etc. is normally not available at this level of design.

Table 6. ANALYSIS DATA REQUIRED FOR TECHNOLOGY EVALUATION

1. Performance

   a. Combat System
      (1) Payload Capacity - Weight, Deck area
      (2) Effectiveness - Weapons, Sensors

   b. Survivability
      (1) Signatures - IR, RCS, Noise, Visual, Magnetic
      (2) Vulnerability Assessment

   c. Mobility
      (1) Sustained Speed
      (2) Range at endurance speed
      (3) Maneuverability

   d. Seakeeping
      (1) Bales' Rank Factor
      (2) Natural Periods - Heave, Pitch, Roll
      (3) Percentage of time ship can perform mission at any heading in most severe design operational area

   e. Operability
      (1) Reliability
      (2) Maintainability
      (3) Availability

2. Cost

   a. Research and Development
   b. Acquisition - Lead, Follow, Average Ship
   c. Operating and Support

3. Risk

   a. Schedule
   b. Technical
   c. Cost

2.4 Technology Impact Evaluation

Technology impact evaluation consists of assessing the ship size, configuration, performance, cost and risk impact of incorporating an emerging technology. If the technology does not improve the performace of the ship and/or reduce the cost/size, then there is no benefit to including it in the design. Hence it is extremely important that the results of the analysis be accurate and reflect the "true" impact of the technology being investigated. This section is therefore concerned with developing a standard methodology for conducting ship impact analysis for a future ship.

The process developed in this section is for assessing the impact of emerging HM&E technologies when the basic performance requirements of the ship are held constant and it is desired to reduce the cost and/or size of the ship. The other perspective is to change the combat capability, survivability, mobility, seakeeping, and/or operability of the ship and then assess the change in mission effectiveness. This alternate approach will not be addressed due to lack of models for assessing mission effectiveness changes at the conceptual level of design. The author recognizes the need for work in this area and hopes this very worthwhile project will be undertaken in the near future.

The basic approach used is to attempt to keep the performance requirements and the design standards and practices constant, then determine the ship, cost, and risk impact of incorporating the technology. This translates to the following rules.

(1) Never allow performance to fall below threshold. Try not to exceed baseline performance (i.e., attempt to keep mission effectiveness constant).

(2) Balance variant in weight, stability, space, and energy utilizing standard design practices and standards. Attempt to keep design margins constant.

(3) Perform a cost analysis. As a minimum this includes lead, follow and average ship acquistion cost as well as operating and support costs.

(4) Identify risk associated with the design. As a minimum this should be a crude assessment similiar to that used in CONFORM feasibility designs, Reference [14].

(5) Assess changes in the ship.

If the above rules are difficult to follow, allow things to vary in the way an intelligent designer would perceive as most rational. However, under no circumstances, should the performance characteristics or design margins be allowed to fall below the minimum criteria. If changes in mission performance and design margins occur, the differences will have to be evaluated. The picture then becomes more clouded and the committment decision more difficult.

In order to assist in following the rules, additional explanation and guidance is provided below.

(1) Normalized Performance

(a) Combat System - same combat system components.
- same integration approach (i.e., topside arrangeability, dispersion, firing arcs, etc.).

(b) Survivability - same degree of protection.
- same signature levels.

(c) Mobility - same range and endurance speed.
- same sustained speed. (Practical considerations such as discrete plant sizes may dictate that V_s changes.)
- same maneuverability.

(d) Seakeeping - will probably change since it is a function of ship size and geometry.

(e) Operability - same degree of onboard maintenance, component reliability, system redundancy, etc., resulting in the same ship RM&A.

(2) Balanced Design

The design is balanced when it possesses no excess weight, stability, space, and energy beyond that required by standard design margins. Try to maintain the same margins as the baseline. However, due to discrete plant sizes this may not be possible. Complete flexibility in changing gross characteristics, hull form, deckhouse, electric plant, HVAC, propulsion plant, etc.. But, do not change subsystems unless necessary to balance ship. Manning should remain constant unless technology directly effects manning levels.

(3) Cost Analysis

The intent is to provide an estimate that can be used to compare the relative costs of competing alternatives. Hence the model must be sensitive to the complexity of the system as well as the weight/size. Cost estimating relationships such as those developed in the Advance Naval Vehicle Concept Evaluation (ANVCE) Study, Reference [25], are considered sufficient.

(4) Risk Assessment

It is very difficult to quantify the risk associated with incorporating a technology innovation in a design. Risk assessment is not the strong point of this thesis. Readers should refer to Reference [34] for a more thorough discussion of the subject.

As a minimum, a simple qualitative system should be used. The one proposed is a simple subjective rating system that addresses the probability of achieving advertised technical specifications within cost and schedule [14]. The following factors are addressed:

(a) Schedule - ability of R&D Program to meet milestones.

(b) Technical - ability of the technology to achieve advertised performance, size, etc..

(c) Cost - ability of program to remain within R&D acquisition, and O&S cost estimates.

Schedule risk is considered to be low, moderate, or high according to the following definitions:

(a) Low - current schedule and funding will provide Approval for Service Use (ASU) or full-scale demonstration by IOC minus 8 years.

(b) Moderate - current schedule and funding will provide ASU or demonstration by IOC minus 6 years. Note that this is prior to lead ship contract award.

(c) High - current schedule and funding will not provide ASU or demonstration by IOC minus 6 years and ability to accelerate is either impossible or unknown.

Six risk categories are defined for assessing the technical risk. Since the objective is to achieve operational ship capability, the low risk category will imply the system has been demonstrated satisfactorily. This definition is used to calibrate the remaining categories.

(a) Low - Technology has been demonstrated satisfactorily on a ship or at a land-base test site. Detailed plans exist for implementing.

(b) Moderately Low - Some testing has been done on ships or land-based test sites. Results and scaling laws are sufficiently understood to permit design within acceptable margins. Some unknowns remain but their impact is unlikely to cause major redesign.

(c) Moderate - Some data exists to indicate that the approach is valid. Unknowns still remain which could require some redesign.

(d) Moderately High - Some testing has been done or experience gained but results have not been totally satisfactory. Several unknowns exist and as they are resolved redesign will be likely.

(e) High - Technology base is mainly theoretical and what testing has been done has not been conclusive. Unknowns exist in sufficient quantity to make any design effort highly conceptual.

Cost is probably best handled in narrative form. The projected funding requirement of the R&D program, and the accuracy of projected acquisition, and operating and support costs should be discussed.

(5) Presentation of Results

Table 7 is proposed for organizing the results of the impact analysis. The indices listed are recommendations, but may not always be relevant. The possible indices are infinite. It is suggested that a standard set be used; additional ones may be utilized depending on the technology being evaluated. For example, it may be interesting to present a comparison of fuel conservation in terms of NM/LT for a technology which provides a reduction in SFC.

Table 8 is proposed for discussing the impact of the technology. The evaluation includes identification of significant impact areas, a discussion of the difficulties encountered in exploiting the technology, and most importantly, identification of areas for further investigation. Unfavorable recommendations may be made concerning the application. However, evaluators should not condemn the idea. They should point out the attributes that could result from other possible applications including integration with other technologies.

Table 7. RECOMMENDED FORMAT FOR COMPARISON OF MAJOR CHARACTERISTICS

	THRESHOLD	BASELINE	VARIANT	DIFF %
Ship Performance				
1. Combat System				
Capacity				
Military Payload				
Int Deck Area				
Effectiveness				
Arrangeability				
2. Survivability				
Signatures				
IR				
RCS				
Noise				
Visual				
Protection				
Blast				
Frag				
NBC				
Shock				
3. Mobility				
V_S				
V_E				
Range				
Maneuverability				
4. Seakeeping				
Rank Factor				
Roll Period				
5. Operability				
RM&A				

Note: DIFF % = 100x(Variant-Baseline)/Baseline

COMPARISON OF MAJOR CHARACTERISTICS (CONTINUED)

	THRESHOLD	BASELINE	VARIANT	DIFF %
Design Margins/Criteria				
1. Margins				
Acquisition Weight	12.5%			
Acquisition KG	12.5%			
Space	0.0%			
Acq Electrical	20.0%			
S.L. Electrical	20.0%			
Propulsion Power	8.0%			
Accommodations	10.0%			
Strength	2.24 KSI			
2. Standards & Practices				
GM_T/B	.08-.12			
FBD_O				
Max Primary Stress				
Correlation Allow	.0005			
Ship Configuration				
1. Gross Characteristics				
LBP				
Beam				
Draft				
Depth				
Displacement				
Total Volume				
GM_T				
Disp Lgth Ratio				
Volumetric Density				
2. Powering				
SHP_I				
SHP_E				
PC_E				
SFC_E				
3. Ship Service				
Propulsion Load				
Average Load				
Peak Elec Load				

COMPARISON OF MAJOR CHARACTERISTICS (CONTINUED)

	THRESHOLD	BASELINE	VARIANT	DIFF %
3. Weight				
W_{100}				
W_{200}				
W_{300}				
W_{400}				
W_{500}				
W_{600}				
W_{700}				
Acqusition Margin				
Lightship				
Loads				
Fuel				
Ship Ammo				
Aviation				
Full Load Weight				
Full Load KG				
Lightship KG				
5. Volume				
Hull				
Deckhouse				
V_1 Mission				
V_2 Human Support				
V_3 Ship Support				
V_4 Mobility				
V_5 Unassigned				
Total Volume				
6. Manning				
Officer				
CPO				
Enlisted				
Accommodations				
<u>Cost</u>				
1. R&D Cost (10 yrs)				
2. Acquisition Cost				
Lead Ship				
Follow Ship				
Average				
3. Operating & Support				
<u>Risk</u>				
1. Schedule				
2. Technical				
3. Cost				

Table 8. RECOMMENDED FORMAT FOR DISCUSSION OF TECHNOLOGY IMPACT

1. Description of Tradeoff

Brief explanation of how technology was incorporated into the design.

2. Areas of Significant Change

List areas of major change.

3. Improvements (Variant vs Baseline)

List indices which showed improvement.

4. Degradation (Variant vs Baseline)

List indices which degraded.

5. Difficulties to Exploit Technology Fully

Discuss difficulties encountered in achieving the maximum payoff potential of the technology. This may include design practices/standards, space requirements, etc..

6. Recommendation

Make a recommendation concerning the application studied.

7. Areas for Further Investigation

Identify possible synergistic combinations, alternate approaches to exploiting the technology, etc..

CHAPTER 3

TECHNOLOGY EVALUATION TOOLS

3.1 Introduction

Design tools are the cornerstone of our ability to conduct technology evaluations. The lack of models available for the early stage assessment of changes in mission effectiveness due to changes in combat system performance, survivability, mobility, seakeeping, and/or operability, has resulted in technologies being evaluated primarily in terms of ship impact (size and configuration) an cost. Other considerations such as reliability, ra[illegible]d noise, risk, etc. are usually handled qualitati[illegible]y. However, it is difficult, for example, [illegible]scribe the advantage of being able to operate an [illegible] helicopter 10% more of the time because of reduced ship motions without a quanitative measure of mission effectiveness. This is an area with potentially high payoff for selling new technologies and should be given more attention.

Table 9 summarizes the current status of technology assessment tools. ASSET was developed specifically for determining the ship impact of a broad spectrum of technologies. Since this thesis deals extensively with ship impact analysis, the ASSET program will be explained in detail in the next section.

Table 9. EVALUATION TOOLS

1. Ship Impact
    * ASSET

2. Cost Models (Acquisition and Life Cycle)
    * ASSET Cost Analysis Module
    * RCA PRICE
    * FAST

3. Performance Characteristics
    a. Combat System
        * PIP
    b. Survivability
        Signatures
            - RCS (CROSS Model)
            - IR (SIREOS)
            - Acoustic (In Development)
            - Wake (Nonexistent)
        Vulnerability
            * SVM
            * Mini-SVM (In Development)
    c. Mobility
        Speed/Range
            * ASSET Performance Analysis Module
        Manuevering
            * MANAST
    d. Seakeeping
        * ASSET Seakeeping Analysis Module
        * SMP
    e. Operability
        * RM&A Models
    f. Manning
        * MDM

4. Mission Effectiveness Models
    * SIDS

5. Risk (Nonexistent)

There are numerous cost models available for estimating acquisition, and life cycle costs. Selection of the appropriate model depends on the amount of information available and the level of accuracy required. Cost was addressed in this thesis using the ASSET Cost Analysis Module.

There is no integrated set of models for evaluating the various performance features of a ship necessary to make an assessment of mission effectiveness. Different organizations have their own models but many require a level of detail not normally available at the early stages of design. For example, the SVM model for assessing vulnerability requires information on cable runs, location of components, etc., which is normally not available until detailed design. The whole area of mission effectiveness needs considerable work before an adequate integrated package can be made available for early stage design.

Risk is usually handled qualitatively. This unfortunately depends on the subjective interpretation of the person making the assessment. Work needs to be done in establishing a more rational approach to risk assessment.

3.2 The ASSET Program

The Advanced Surface Ship Evaluation Tool (ASSET) is an interactive, computer-based HM&E technology evaluation tool. Its purpose is to support rapid but systematic evaluation of the impact of a broad range of existing and emerging technologies on the size and configuration of naval ships. The following discussion of the program was derived from references [11] and [12], and the ASSET Theory Manuals.

ASSET employs computational modules with state-of-the-art engineering capabilities appropriate for feasibility level studies. The program's orientation has been toward technology evaluation rather than actual design, however, it is currently undergoing revisions which will merge it with DD08, NAVSEA's synthesis model for early stage design.

The ASSET "family" currently includes three distinct ship types: monohull surface combatants, hydrofoils, and small waterplane area twin hull ships (SWATHs). A planing craft version also exists but is not yet documented.

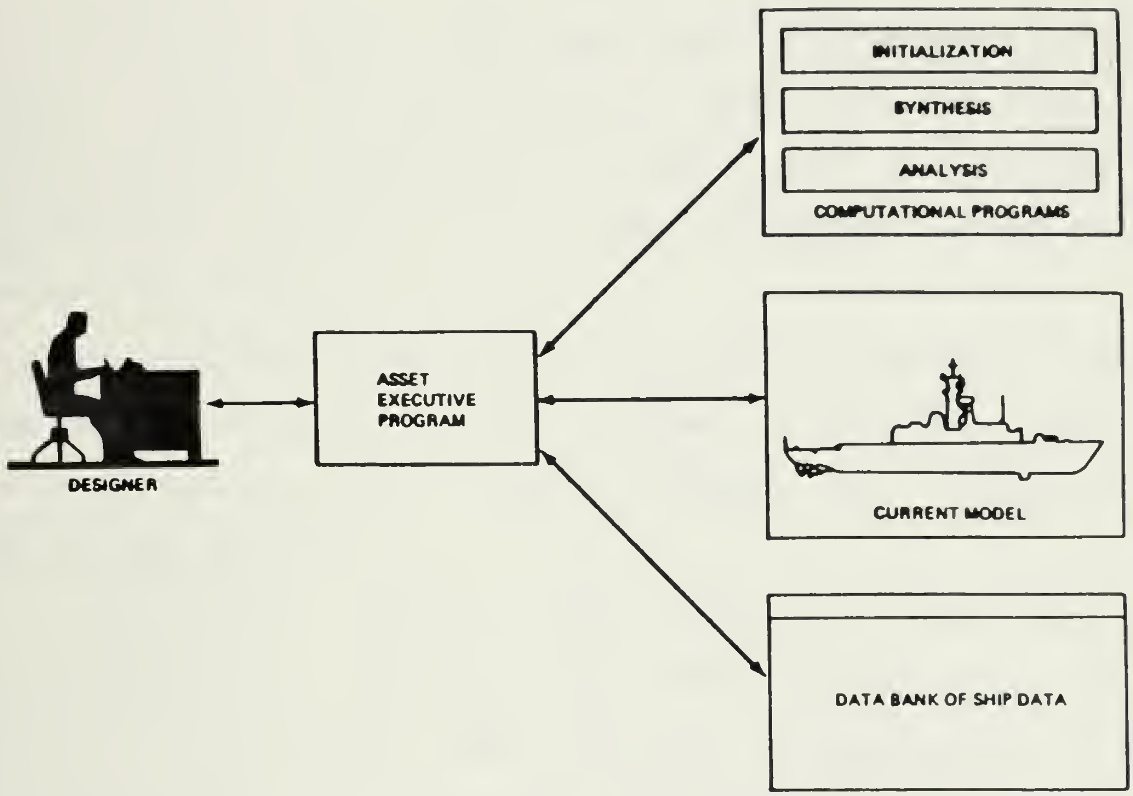
The structure of the ASSET system is illustrated in Figure 4 and comprises five basic components.

(1) The design team

(2) The executive program which interprets the designer's commands

(3) The "current model" which is the data list that uniquely describes the ship being studied

Figure 4. THE ASSET SYSTEM CONCEPT



(4) The data bank which stores the parameters needed to describe ships and components

(5) The computational modules which perform the analytical calculations

The design team is the most important component of the system. Computer programs do not release the user from from making conscious decisions, but rather offer the freedom to explore more alternatives and spend a greater percentage of design time in decision-making.

The executive program is the linking mechanism between the user and the computational programs. Its primary function is to interpret the user's commands and execute the appropriate functions.

The current model is the temporary data list of parameters that describes the ship configuration being studied. The current model consists of approximately 250 parameters which, collectively, are called the model parameter list (MPL). The current model is the only source of data for input to the computational programs and serves as a repository for data output by them. To be preserved, the current model must be transferred to the data bank.

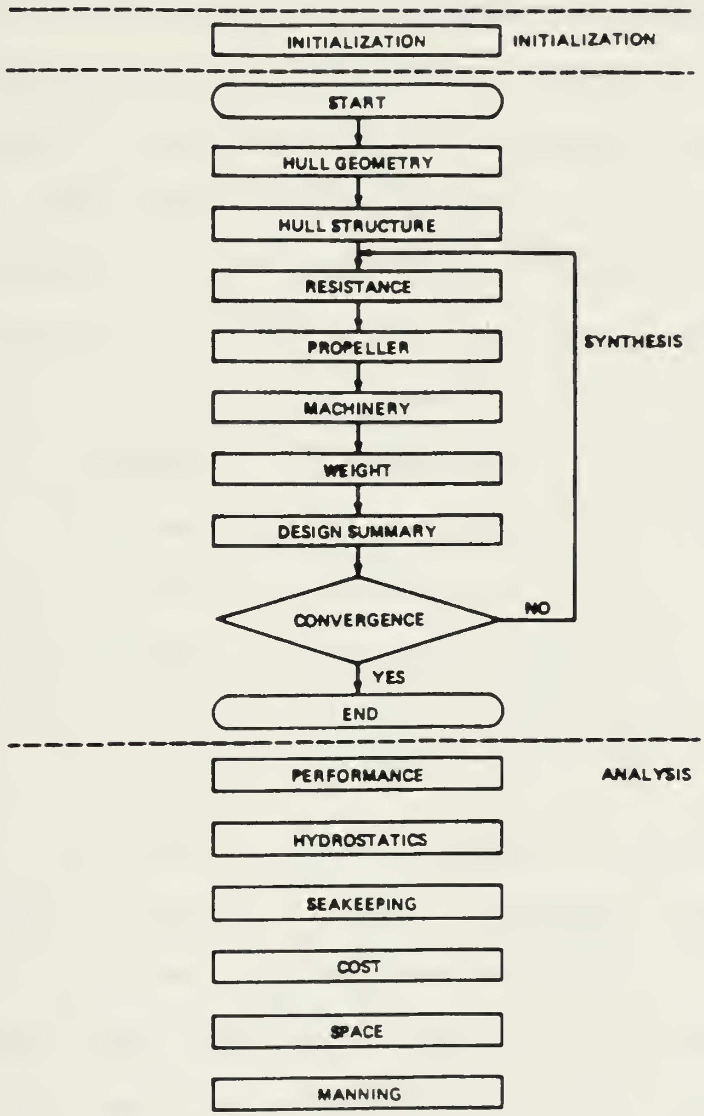
Data banks permit the permanent storage of the ASSET parameters that describe previously designed ships and subsystems of ships called components. Ship data banks are used to store the complete MPL for up to 20 ships. Component data banks may be used to store user-defined subsets of the MPL description. In both cases, data are stored in the data

bank under a user-selected name and may be recalled to the current model by a simple command.

The computational modules define the technical capabilities of ASSET, hence, they vary depending upon the type of ship being considered. The following discussion applies to the monohull surface combatant (MONOSC) computational modules within version 1.2. The fourteen computational modules within MONOSC are grouped into three principal functional types: initialization, synthesis, and analysis. This arrangement is illustrated in Figure 5. An important distinction to be made between analysis and synthesis modules is that the execution of an analysis module does not change the current module. Each module represents a particular ship design discipline with the exception of the Initialization and Design Summary Modules. The user has the option of executing any one of the computational modules independently. Modules within the synthesis portion may also be executed in a sequential loop that achieves a final closure when ship weight is equal to displacement. This design spiral is indicated by the START, WEIGHT CONVERGENCE, and END items in Figure 5.

It is important to note that only a weight equals displacement convergence is achieved and that a "totally balanced" ship is not guaranteed by the automatic convergence on weight alone. To obtained a balanced ship, the user employs analysis modules to assess space and stability

Figure 5. ASSET MONOSC COMPUTATIONAL MODULES (Version 1.2)



characteristics of the weight balanced ship. If either space or stability characteristics are found unacceptable, the user must decide on the best solution, implement changes to the ship, and determine success by repeating the above sequence until all requirements are satisfied. This is a desirable feature for certain types of impact studies such as those concerned with modifications to existing ships where hull shape and structure are fixed. For studies that involve generation of entirely new ship configurations, where geometry and structure are variable, this approach can lead to a great deal of user involvement in balancing the ship. Planned improvement to the program includes an option for automated closure on weight, space, and stability.

The following provides a brief description of each of the fourteen computational modules within MONOSC version 1.2.

INITIALIZATION - The Initialization Module is an abbreviated, empirically based version of the Synthesis and Analysis portions of the program. The primary function of the module is to improve the starting point for more detailed calculations and iterative procedures found in Synthesis and Analysis portions of the program. Because it is parametric, Initialization lacks direct sensitivity to many technologies that can be explicitly addressed in the more detailed Synthesis and Analysis modules.

HULL GEOMETRY - The Hull Geometry Module provides the hull shape and superstructure as well as internal decks and bulkheads. Hull offsets in the Current Model can be scaled and warped to define a new hull form and/or superstructure that meets required physical characteristics. The Hull Geometry Module is not currently included within the automated convergence loop. Thus, any convergence is for the single geometry provided by the module. That is, displacement is adjusted by changing the draft.

HULL STRUCTURE - The Hull Structure Module employs a first principles approach to determine the structural scantlings of the configuration defined in the Hull Geometry Module. The calculations are based upon pressure loading data which are either calculated by the program or designer-input. For example, hull-girder bending moments estimated by ASSET are based on a curve fit of design bending moments from 13 destroyers and frigates. Plating scantlings are determined at three longitudinal locations for the hull bottom, sides, and weather deck. Additional scantling data are calculated for internal decks, bulkheads, frames, girders, beams, and stiffeners. The module does not perform a structural design of the deckhouse. The approach is valid for homogenous isentropic materials. A material may be selected from a list of standard materials (MS, HTS, HY80, HY100, HY130, Al 5086, or Al 5456). Otherwise the material properties must be specified by the user.

RESISTANCE - The Resistance Module calculates ship drag over a range of ship speeds. Calm seas and a clean hull are assumed. The total ship resistance is computed as the sum of frictional resistance, residuary resistance, appendage resistance, wind resistance, and a resistance margin. Taylor Series data as modified by the application of a speed/length ratio dependent "worm curve" are used to calculate residuary resistance. Frictional resistance is computed using either the ATTC or ITTC friction line.

PROPELLER - The purpose of the Propeller Module is to characterize a feasible propeller capable of transmitting design thrust within the constraints of cavitation, RPM, and other considerations. Three propeller types are considered: fixed pitch , controllable pitch , and contrarotating. The user can select among three propeller design methods: ANALYTIC, TROOST or MODEL. The ANALYTIC method uses regression data from the results of a series of lifting line calculations. The TROOST method uses data from the Wageningen B-screw series. Troost cannot be applied to contrarotating propellers. The MODEL method requires user-specified open-water data.

MACHINERY - The Machinery Module performs several functions. Electrical power requirements, propulsion engine characteristics, transmission efficiences, endurance fuel weight, sustained speed, and endurance speed are calculated by

this module or specified by the user. Maximum speed (speed at 100% of installed power) is always calculated. The system configuration (engines, transmissions, propellers, etc.) must be specified. The options are listed in Table 10.

WEIGHT - The Weight Module estimates weights and KGs to the 3-digit level according to the U.S. Navy's Ship Work Breakdown Structure (SWBS). The majority of weights are estimated by epirical formulae. The module permits the user to adjust the estimated weight and center of gravity of each weight group.

DESIGN SUMMARY - The Design Summary Module produces output to the user that summarizes the results of computations of the six synthesis modules. Output from the Design Summary Module is often more convenient to scan than output from each of the synthesis modules. This module can also provide a matrix format listing of combat system information from the Current Model.

PERFORMANCE ANALYSIS - This module calculates the performance characteristics of the design over a wide range of conditions. The Performance Analysis Module considers fouling effects of marine organisms, degradation of machinery with time, mission profile, and sea state. A variety of low speed and off-design performance characteristics may be estimated within this module.

Table 10. ASSET MACHINERY PLANT OPTIONS[1]

Main Engine Type	Gas Turbine, Diesel, Gas Turbine and Steam (COGAS)
Secondary Engine Type	Gas Turbine, Diesel, COGAS, None
Ship Service Type	Gas Turbine, Diesel, Propulsion Derived
Transmission Type[2]	Mechanical, AC/AC, DC/DC, AC/DC, DCS/DCS, AC/DCS
Propeller Type	Fixed Pitch (FP), Controllable Pitch (CP), Contrarotating (CR)

Notes:

(1) See ASSET Theory Manuals for selection implications and limitations.

(2) The first acronym indicates generator type and the second specifies motor type. For example, AC/AC indicates an AC generator with an AC motor for propulsion, both water cooled. Only one type of totally superconducting (DCS/DCS) system is considered. The AC/DCS system has a normally conducting AC generator with a superconducting DC motor.

HYDROSTATIC ANALYSIS - This module provides the capability to perform a detailed hydrostatic analysis including curves of form, intact stability, floodable length, damaged static stability and maximum vertical center of gravity positions allowed by NAVSEA Design Data Sheet DDS 079-1 criteria. This module is based on the Navy Ship Hull Characteristics Program (SHCP).

SEAKEEPING ANALYSIS - The Seakeeping Analysis Module calculates a relative ranking based on the work of N.K. Bales. Ranking is assumed to be a linear function of six geometric parameters characterizing the underwater hull form. The ranking is for a normalized displacement of 4300 tons and considers pitch and heave motions only.

COST ANALYSIS - The Cost Analysis module estimates ship costs for the purpose of tradeoffs and comparative evaluations. Both unit acquisition and life cycle costs are addressed. Simple empirical relationships based on the SWBS weight group estimates are used to estimate construction costs. Life cycle costs are estimated utilizing a variety of data. The algorithms used in this module were adapted from the the Advanced Naval Vehicle Concept Evaluation (ANVCE) study cost module.

SPACE ANALYSIS - The Space Analysis Module estimates the total volume and area requirements of the ship based on empirical formula and standards. The space statement follows the Navy Ship Space Classification System (SSCS). If the generated space estimates prove to be unsatisfactory, the user can make adjustments.

MANNING ANALYSIS - This module allows the user to estimate manning requirements from two perspectives: departmental and functional. In departmental manning analysis the number of officers, petty officers, and enlisted men assigned to each department is calculated. The functional workload analysis is estimated using eight assumed manpower requirements for readiness Condition III (Wartime Steaming). The weight driven algorithms used in this module were developed from U.S. Navy historical manning data for frigates, destroyers, and cruisers.

The majority of computational modules employ analytical, rather than empirical, algorithms. This approach allows the user to investigate a large number of configurations and technical options. A sample list of HM&E technologies and an assessment of ASSET's current capability to handle them is provided in Table 11. It is worth mentioning that the ability to construct such a chart is a tribute to the superb documentation which adds immeasurably to the program's flexibility.

Table 11. ASSESSMENT OF ASSET MONOSC's ABILITY TO EVALUATE THE SHIP IMPACT OF DIFFERENT HM&E TECHNOLOGIES

	How Technology Would be Handled		
Functional Area	Directly	Indirectly	Cursorily
1. Containment			
a. Material			
* HTS	x		
* HY-80	x		
* HSLA	x		
* Al 5086	x		
* NAVTRUSS DKHS		x	
* Composites			x
b. Structural Concept			
* Lt WT Foundations		x	
* No Frame concept			x
c. Protection			
* 7 psi blast	x		
* RCS reduction geom	x		
* Magazine protection		x	
* VLS Armor		x	
* KEVLAR		x	
2. Main Propulsion			
a. Main Engine			
* COGAS	x		
* CODOG	x		
* IRGT		x	
* IR Reduction		x	
b. Transmission			
* AC/AC Liq Cooled	x		
* Superconducting	x		
* Geared Elec Drive			x
* Eplicyclic gears	x		
* Hardened gears		x	
* Mech Cross Connect			x
* Composite Shafting		x	
* Bearing in Post		x	
c. Propulsor			
* Contrarotating Prop	x		
* Waterjet			x
* Pods			x
3. Electric Machinery			
* Prop Derived SSG	x		
* Rotary Engine SSG		x	
* Pwr Factor Corr		x	
* Lt WT Cable		x	
* Advanced Batteries		x	
* Fuel Cells			x
* Fly Wheels			x

ASSESSMENT OF ASSET MONOSC (CONTINUED)

Functional Area	Directly	Indirectly	Cursorily
	How Technology Would be Handled		
4. Auxiliary Machinery			
* Prairie Masker	x		
* CPS	x		
* Fin Stabilizers	x		
* Pitch Control Fins		x	
* Reverse Osmosis		x	
* Rotary Air Comp		x	
* GRP Piping		x	
5. Outfit/Human Support			
* GRP Ladders		x	

Rating System:

Directly - The ability to evaluate the technology was specifically designed into the program. The technology can be incorporated by selecting the appropriate indicator option.

Indirectly - The flexibility to correctly model the technology was designed into the program. The technolgy can be incorporated by setting an indicator to OTHER and supplying the necessary data and/or making minor weight/volume adjustments.

Cursorily - Automated closure feature of the synthesis loop can not be used. Extensive analysis outside of the program is necessary. Additional algorithms would have to be incorporated into the program before it could adequatedly model the technology.

Notes:

(1) Table reflects ability to determine ship impact, not the abilitiy to assess vulnerability, signatures, operability, etc.

(2) List is by no means all inclusive. Intent is to provide a sampling to give an indication of the wide range of technologies that ASSET handles and to provide some guidance in future development of the program.

CHAPTER 4

ASW FRIGATE CASE STUDY

4.1 Introduction

This case study was conducted in order to validate the proposed methodology for the assessment of emerging technologies for naval combatant ships. The steps used in carrying out this case study are outlined below.

(1) Develop a baseline ship following the guidelines of section 2.3.

(2) Conduct a technology survey and select candidate technologies.

(3) Write up technology characterizations.

(4) Perform individual technology impact analysis following the guidelines of section 2.4.

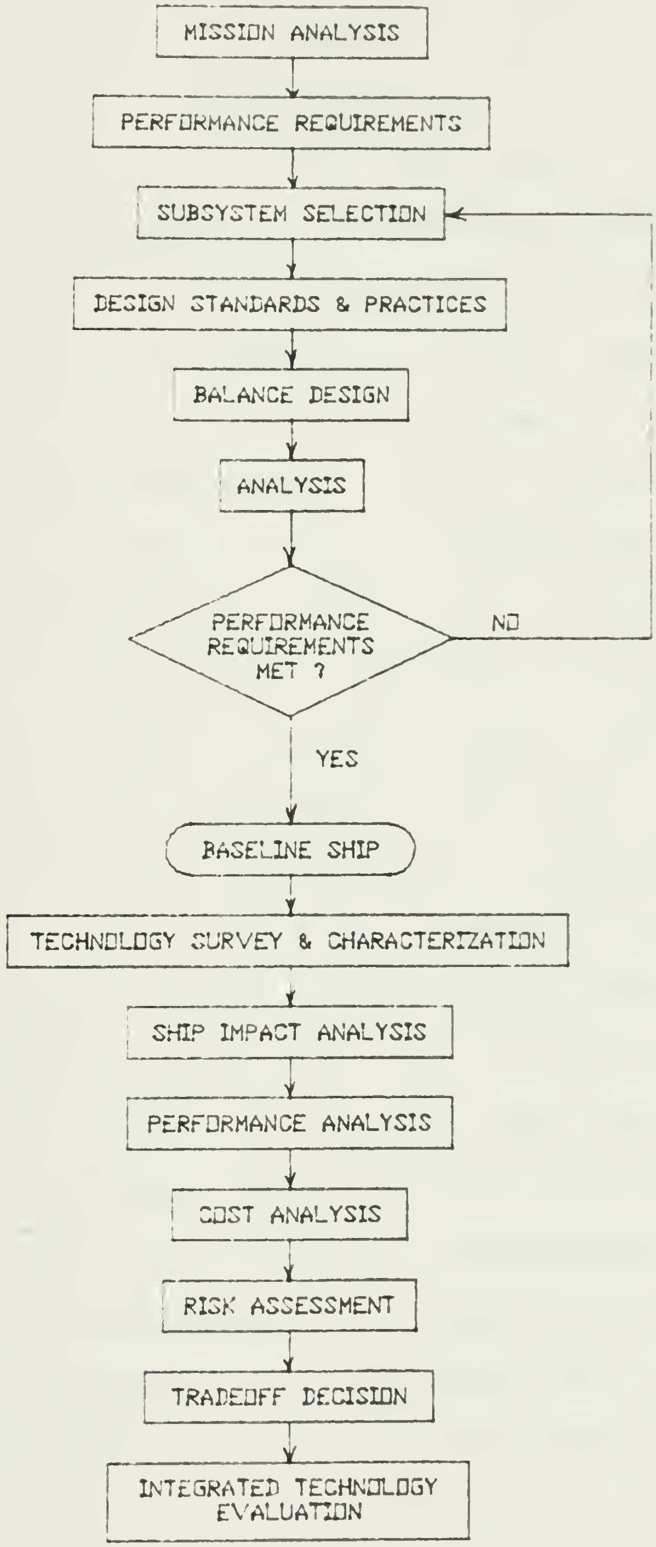
(5) Present tradeoff for the decision maker.

(6) Perform an integrated technology impact evaluation.

A frigate was chosen for this study because of its' timely nature and hope that the results of the technology impact evaluations will be useful in the Naval Sea System Command's (NAVSEA) efforts. Figure 6 displays the sequence followed.

The initial action consisted of a mission analysis and statement of need for the ship. From this analysis, performance requirements were specified and a design philosophy was established. Once the requirements had been determined, subsystems that would meet the performance

Figure 6. CASE STUDY APPROACH



requirements and be acceptable to decision makers were chosen for the baseline ship. This translated to using "off the shelf" systems or ones that were sufficiently along in development to be considered fairly low risk. Design standards and practices to be employed in the design were chosen. Since the design is a conventional monohull, standard USN design practices and criteria were utilized.

The baseline was balanced in space, weight, stability, and energy. The design was then analyzed to ensure it met the performance requirements and to obtain the data necessary for the tradeoff studies. Once a statisfactory baseline was obtained, a technology survey was conducted. Promising technologies with potential payoffs in terms of improving military effectiveness, enhancing operability, reducing size, and reducing cost were selected for impact studies. These technologies were then characterized in the format recommended in section 2.2. Ship impact was determined using ASSET. The effect on seakeeping was evaluated using Walden's extension to Bales' work given in Reference [17]. Cost was assessed using ASSET's Cost Analysis Module. A crude risk assessment was then made of the design variants so that a risk-versus-benefit appraisal could be made for incorporating each of the technologies. The results of the individual technology impact studies were presented and the synergistic combination which appeared most promising was then integrated into the baseline.

4.2 Mission Analysis

The motivation for the design stems from the need for a replacement frigate for the Knox and Garcia class frigates. In addition, a means to counter the increasing threat of the cruise missile nuclear attack submarine (SSGN) is needed. Mission analysis calls for an Anti-Submarine Warfare (ASW) escort capable of operating at considerable distances from the carrier in a hostile environment. Consequently, the ship will need to have a low signature, to possess significant sensor advantages over the SSGN, and to be equipped with standoff ASW weapons. In addition, because the submarine is little effected by sea state, the frigate must be capable of performing in severe sea states. Since it will be operating with a carrier battle group, it will require an endurance and sustained speed compatible with other units in the group. A minimum of thirty ships, two per aircraft carrier (CV) battle group, with an initial operational capability (IOC) of 2005 is deemed necessary.

4.3 Performance Requirements

The performance requirements for the ASW frigate are summarized in Table 12. They reflect an overall feeling that the design should be a highly capable ASW platform and not simply an economical escort with mediocre capabilities. However, it is not intended to be a multimission destroyer and hence, possesses only self defense capability in AAW and SUW.

The frigate will operate at considerable distances from the battle group. Therefore, a low detectable signature is essential for the survival of the platform. Radar cross section (RCS) and infrared (IR) levels should be better than DDG-51, while acoustic and wake levels should be better than DD-963. RCS and IR reductions will be primarily achieved through arrangements and hull/superstructure configuration.

Redundancy of vital equipment and fault tolerance of digitally multiplexed systems are also extremely important factors for the ship's survivability. Ability to prevent the "cheap kill" must be designed into the ship from the onset. This includes fragmentation protection of cable runs, vital spaces, and topside equipment. In addition, imaginative arrangement schemes can reduce the probability of losing all combat capability with a single hit.

An endurance of 4500 NM is justified because of the distances that the ship will be operating away from the rest of the units in the battle group. A sustained speed

Table 12. ASW FRIGATE PERFORMANCE REQUIREMENTS

1. Combat Capability

* Command and Control
  - Control ASW aircraft
  - Integrate ASW sensors
  - Two way data link with battle group

* Area capability in ASW
  - Passive detection and localization
  - Active ranges to second convergence zone
  - Standoff weapon delivery capability

* Self defense capability in AAW and SUW

2. Survivability

* Signatures
  - RCS and IR better than DDG-51
  - Acoustic and wake better than DD-963

* Protection
  - blast (3 psi)
  - frag (Level II - cable ways, vital spaces, magazines, topside equip)
  - NBC (partial CPS)
  - shock (.3 Keel Shock Factor)

3. Mobility

* V_s > 24 KT in sea state 5
* Endurance of 4500 NM at 20 KT
* Stores period (dry 45 days, chilled 30 days, frozen 45 days, general 45 days)
* Manueverability consistent with other escorts

4. Seakeeping

* Conduct flight ops 75% time winter N. Atlantic
* Sonar not significantly degraded through S.S. 5

5. Operability

* Similar to FFG-7 in onboard maintenance and sustainabiliy capability

ASW FRIGATE PERFORMANCE REQUIREMENTS (CONTINUED)

6. <u>Manning</u>

* No unit commander
* Accommodations similiar to DD-963

7. <u>Planned Use</u>

* Environment
  - Operate all oceans
  - Most severe: Winter N. Atlantic

* Operating Profile

Speed - KT	% time
6	12
14	45
20	38
24	5

Annual operating hrs - 2500

requirement of 24 knots in sea state 5 is considered more realistic than a calm water speed requirement.

The frigate must be capable of conducting ASW operations even during winter conditions in the strategically important North Sea. Hence, it was determined that the ship must be able to conduct helicopter flight operations at least 75% of the time (any heading) during winter conditions and the sonar suite must not be significantly degraded. The operability of the ship should be at least as good as FFG-7. Manning is expected to be similar to DD-963 (based on anticipated size and combat system). The projected operating profile was derived from a standard escort mission profile.

In order to assist in subsystem selection and provide guidance for tradeoff decisions, the design philosophy presented in Table 13 was developed. The overriding goal for the design is a signature and ASW capability allowing engagement of subsurface threats prior to weapons launch against the battle group, even in severe sea states.

Since the frigate will be operating in patrol areas far in advance of the carrier, mobility and operability are important considerations. The ship is intended to be a highly capable ASW platform. But since it possesses area capability in only one major warfare area, it should be significantly less expensive than a multimission destroyer. It is anticipated that the ship will serve over a lifespan of 30

TABLE 13. ASW FRIGATE DESIGN PHILOSOPHY

1. ASW Capability (10)
2. Signature (10)
3. Seakeeping (8)
4. Mobility (6)
5. Operability (4)
6. Acquisition Cost (4)
7. Self Defense Capability (3)
8. Protection (3)
9. Technical Risk (2)
10. Operating and Support Costs (2)

Notes:

(1) Order should be construed as a prioritization.

(2) Numbers in parenthesis represent weighting factors for tradeoff analysis.

years, hence it is appropriate to address operating and support cost. However, in order to afford at least 30 ships, acquisition cost should be given priority.

If the ambitious goals of the design are to be achieved, it will be necessary to embrace emerging technologies. This requires that a significant degree of risk will have to be accepted. However, the level may be reduced by applying efforts early to minimize the risk in the critical areas identified by the impact studies.

4.4 Baseline Development

Development of the baseline ship began with identification of feasible subsystem candidates. The major subsystems (combat system, hull form, and propulsion plant) were narrowed down first. Conceptual sketches were drawn of various configurations, and the most feasible selected. Then the remaining subsystems were selected, design standards and practices such as margins, stability criteria, etc. were determined, the design was balanced, and then analyzed to ensure it met all the performance requirements.

The combat system selected for the ASW frigate is summarized in Table 14. This combat suite will provide the frigate with adequate sensors and weapons to allow the ship to engage the submarine prior to weapon launch against the battle group. In addition, the suite provides sufficient self defense capability in both AAW and SUW for the frigate to operate in a hostile environment at distances up to 250 NM from the carrier. An air search radar is not provided. This is considered consistent with maintaining a low signature and using passive detection. Mutual support will be provided by the Combat Air Patrol (CAP) and AEGIS platforms.

In the area of command and control, the frigate will possess an advanced ASW control system that will provide integration of sensor data, assist in classification and target localization, and provide tactical information to the battle group via a directional data link.

Table 14 ASW FRIGATE COMBAT SYSTEM DESCRIPTION

Command & Control
- Integrated ASW Command & Control

Exterior Communication
- FFG-7 Exterior Comm Suite

Sensors
- Surface Search Radar
- Navigation Radar
- IR Dectector
- Passive Conformal Sonar Array
- Towed Array
- Low Frequency Active Sonar
- Active ECM
- MK-92 FCS

Armament
- 76mm Gun - AA Module
- Two CIWS (12000 rds)
- Tactical VLS (32 cell ASROC/Harpoon) - A Module
- VL Seasparrow (16 missiles) - AA Module
- SRBOC
- MK-32 SVTT

Aircraft
- Three LAMPS III

In order to offset future threat quieting, coating, and operational capabilities, the ASW frigate will need to possess a highly advanced integrated sonar suite. The system that is envisioned is similar to that being considered for our next generation of fast attack nuclear submarines (SSN). It will provide bottom bounce and second convergence zone detection, improved tracking and localization accuracy, and integrated sensor data and information processing in support of targeting. As a result, the acoustic arrays will be much larger than those currently on surface combatants and the impact on the new design will be great.

The sonar suite for the frigate will probably be comprised of the four basic subsystems listed below.

(1) Conformal Array

(2) Towed Array

(3) Low Frequency Transmit Array

(4) Integrated Signal and Information Processing

The exact configuration of the subsystems (i.e., geometry of arrays, multi-line or simple towed array, etc) is not yet solidified. However, weight and size estimates are obtainable from first principles. The large acoustic arrays could either be placed behind a dome, located exterior to the hull and faired, or recessed in the hull lines. The recesed array option appears to be most advantageous from a ship impact standpoint and was therefore selected for the baseline

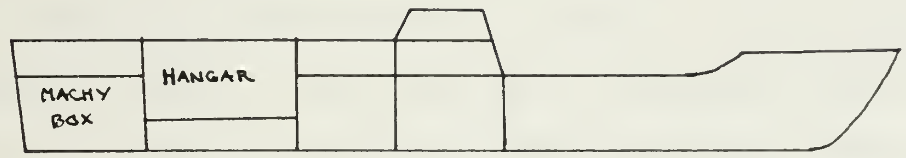
frigate. Some acoustic problems may exist with recessed arrays. Signal processing becomes more complicated and hence, expensive with an array that possesses double curvature. But, the advantages of better survivablity, powering, and less weight make the option attractive.

The major weapon systems (Tactical Vertical Launch System, Vertical Launch Seasparrow, and 76mm Gun) use standard modules developed by the Ship Systems Engineering Standards (SSES) Program. These standards minimize the costs of ship conversion and repair, and increase the availability of the platform. Other weapon systems carried include 20mm Close In Weapon System (CIWS), and Surface Vessel Torpedo Tubes (SVTT).

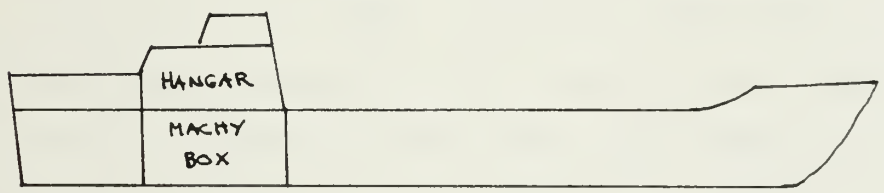
After the combat system was selected, hull/superstructure configurations were investigated. The conceptual sketches shown in Figure 7 represent the results of this "brainstorming". The first configuration shown has an elevator and hangar deck. Though highly desirable from a flight operations standpoint (minimum superstructure to shed vortices), the weight, size, and maintenance requirements of the helo support equipment were considered excessive. The next concept was an attempt at a forward flight deck. This is preferred by the aviation community because it avoids the turbulence problem. However, this configuration was ruled out because the flight deck would be unservicable in high sea states. The third configuration was the one chosen for the baseline. It is a fairly conventional arrangement with the

Figure 7. ASW FRIGATE CONCEPTUAL SKETCHES

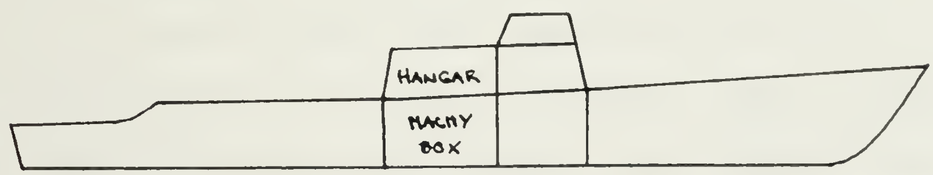
(1) Elevator and Hangar Deck



(2) Forward Flight Deck



(3) Conventional



hangar in the superstucture and the flight deck aft. However, the relatively small superstructure enhances survivability and flight operations. Once the basic configuration was chosen, it was then possible to select the subsystems listed in Table 15 for the baseline.

HULL 23, developed at the David Taylor Naval Ship R&D Center (DTNSRDC), was chosen for the parent hull form because of its' superior seakeeping and resistance performance. The methodology that lead to the HULL 23 configuration is documented in Reference [15]. This hull form is characterized by a large waterplane, sharp "V" sections in the forebody, "U" sections in the afterbody, and a wide transom stern.

A minimum size steel superstructure with 10 degree flare was preferred because of survivability and helo operations. High Tensile Strength steel (HTS) was chosen for the hull and superstructure material because it is the de facto standard and would provide a good basis for material tradeoff studies.

Electric drive was selected for propulsion because it is inherently more survivable than conventional mechanical drive systems (redundant power paths and arrangement flexibility). Also, it cross couples the shafts providing fuel savings by allowing cruising on one gas turbine. Water cooled AC motors and generators were utilized for their improved power density. Direct drive was selected because of its' simplicity.

Gas turbine ship service generators were favored over diesel due to acoustic considerations. The auxiliaries and

Table 15. ASW FRIGATE BASELINE SUBSYSTEMS

1. Combat System
   - see Table 5-3

2. Containment
   a. Hull Form - HULL 23 Variant
   b. Material - HTS
   c. Superstructure - Min size, HTS, 10° flare

3. Propulsion
   a. Main Engines - Two LM2500 Gas Turbines (GT)
   b. Transmission - Direct Drive Electric (Water cooled AC/AC)
   c. Propulsor - Twin Screw, Fixed Pitch (FP)

4. Electric Plant
   a. Prime Movers - GT
   b. Generators - Four 1500 KW
   c. Frequency Conversion - Solid State

5. Auxiliaries
   a. Electric auxiliaries
   b. Partial CPS
   c. Praire Masker
   d. Twin Rudders
   e. Anti-Roll Fins
   f. STREAM UNREP gear
   g. Compensated fuel system

6. Outfit/Human Support
   a. Habitability - modern
   b. Stowage - Vidmar

human support are fairly conventional and require little explanation.

Once subsystem selection was complete, the design was balanced using the Advanced Surface Ship Evaluation Tool (ASSET). The Initialization Module was run to achieve design consistency and to obtain an estimate of hull size. The results showed that if the ship was constrained to float at the design waterline defined by the HULL 23 geometry, it would have significant volume beyond that required by the payload and support systems. While the concept of an "enlarged ship" is viable, it violates entrenched design practice and will not be investigated; the excess volume would cloud impact studies. Consequently, the synthesis section of ASSET was run, allowing the ship to float at a deeper draft. This was done to achieve a space balance and to allow adequate immersion of the sonar arrays. A raised deck similiar to the Edkins' proposed deck in Reference [20] was added to meet the minimum freeboard requirements specified in Design Data Sheet (DDS) 079-2.

The minimum size of the superstructure was estimated from combat system deck area requirements and past designs. For example, pilot house and uptake requirements were obtained from FFG-7 data. The size estimate is presented in Table 16, and the rough layout is displayed in Figure 8. This estimate is needed because ASSET requires the size of the superstructure as an input. Once the superstructure size was estimated, the length between perpendiculars and beam were

Table 16. ASW FRIGATE SUPERSTRUCTURE ESTIMATE

MAIN DECK		AREA [FT²]
Helo Hangar		3000
Uptakes		594
Torp Mag		533
Sonobuoy strm		267
Flight Equip		360
Decon		200
Bos'n Strm		100
	Total	5054

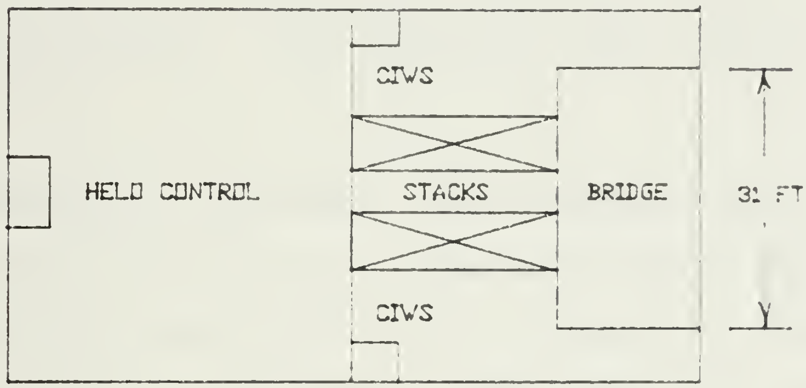
0-1 LEVEL		
Helo Hangar		3000
Uptakes		594
CO Sea Cabin		250
Radar Equip Rm		400
EW Equip Rm		200
Elec Clg Equip Rm		150
Water Closet		80
CIWS Mag		144
Fan Rm		250
	Total	5068

0-2 LEVEL		
Pilot House		512
Chart Rm		80
Helo Control		60
Signal Bridge		60
	Total	712

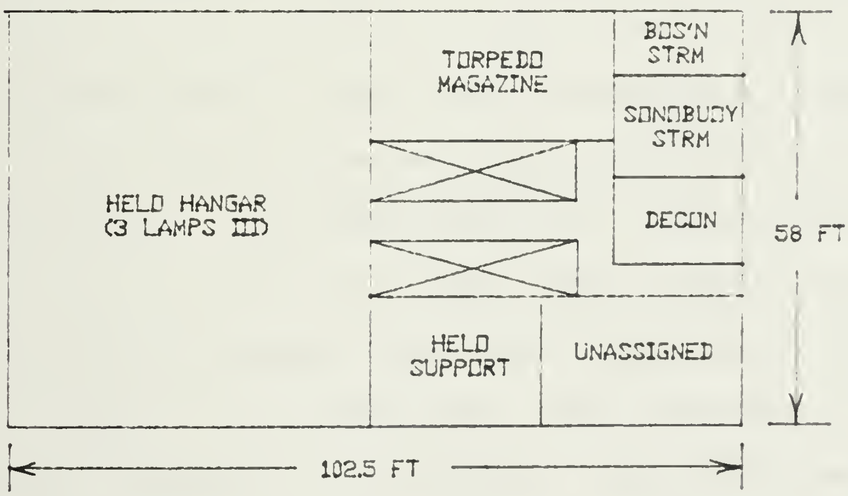
Total Required Area 10834

NOTE: Uptake estimate (27x22) includes centerline passageway

Figure 8 ASW FRIGATE PRELIMINARY SUPERSTRUCTURE LAYOUT



O-2 LEVEL



MAIN DECK

adjusted until a design balanced in weight, stability, space, and energy was achieved. The characteristics of the resulting baseline design are given in Table 17.

The data was scrutinized to ensure the baseline was a reasonable design. The following items were examined in detail.

(1) Aesthetics - The design looks sleek and uncluttered (see profile in Figure 9). Freeboard forward was driven by DDS 079-2 requirements, but it appears excessive. The droop snout proposed by Bales may be appropriate if firing arcs, visibility, and/or weight become an issue.

(2) Gross Characteristics - The large sonar suite impacts heavily on the design. Once this is considered, the basic parameters appear quite reasonable (See Reference [23] for normal parameter ranges for USN monohull surface combatants). The displacement to length ratio is higher and the L/B ratio is lower than desired for powering. But when the payload and steel deckhouse are considered, the numbers are justified. The payload is relatively dense compared to the volume intensive missile ships. This accounts for the high payload fraction and volumetric density. The deep draft is to immerse the sonar. The steel deckhouse and raised deck resulted in the low L/B ratio in order to obtain adequate stability at the length dictated by a space balance.

(3) Powering - Powering performance is remarkably good for such a short beamy hull. The propulsive coefficient (PC) at endurance is suspect. Further investigation reveals that the high PC is due to a high open water propeller efficiency (0.78). The analytic results were verified by a Troost calculation (0.76); thus, the high efficiency can probably be attributed to the large diameter and low RPM of the propeller

(4) Ship Service - The peak KW requirement appears to be low in comparison to the average. This is due in part to the poor definition of the combat system requirements and in part due to questionable estimating algorthms in ASSET.

(5) Weight - Percentages are allocated as expected. The group one weight fraction is somewhat low. This can be attributed to the structural efficiency of a short beamy hull with a relatively large depth, and to the use of HTS. Group 400 weight fraction appears high because of the practice of including sonar water in with electronics.

(6) Stability - The metacentric height is adequate.

(7) Arrangeability - In addition to a volume balance, the required arrangeable deck area was compared with available deck area to ensure there was adequate space. The large objects given in Table 18 were laid out in Figures 10 and 11 to verify they could be adequate arrangement in the baseline ship.

(8) Margins - The design is well balanced with sufficient margins. The electric margin is exceptionally close considering the fact that standard size generators must be used.

In summary, the baseline appears to be highly plausible. It is well balanced, meets basic performance requirements and is not too extreme. It is fortunate to note that the theory has been written, Reference [23], for a comparative analysis module for ASSET which will perform most of the design review necessary to assess design reasonableness.

A seakeeping analysis and cost estimate were performed on the baseline to obtain additional data for the technology assessments. The seakeeping analysis is a simple prediction based on Bales' seakeeping rank factor with the Walden extension that incorporates the effect of displacement. The resulting factor of 13.0 for the baseline is compared with other known designs in Figure 12. As expected, the baseline ship is significantly better than current designs. However, it is ranked somewhat less than the HULL 23 parent. This is due in a large part to the higher T/L ratio of the baseline design. It is interesting to note that the British designers believe that the T/L term in Bales' equation has the wrong sign. They base their criticism on the fact that likelihood of slamming is increased as T/L is decreased. Therefore, differences in the ranking between the baseline and the HULL 23 parent should probably not be of concern.

Figure 12 represents the concept of equivalent dispacements to achieve equal Rhat rankings. Using the FF-1052 design as an example, it is shown that FF-1052 would have to be scaled (geosim-ed) to approximately 7300 tons to achieve the same ranking. Similarly, the equivalent displacements (to achieve R = 13.0) for FFG-7 and DDG-51 would be 6700 and 6000 tons repectfully.

Cost estimates were obtained from the ASSET Cost Analysis Module. Cost data produced by the module are not intended to be of the quality required for budget planning. The intent of the module is to provide data which can be used to evaluate the relative costs of competing systems.

Two basic types of cost were computed. The first was ship acquisition costs. Cost estimating relationships (CERs) are used to calculate lead and follow ship construction costs, profit, cost of change orders, NAVSEA support costs, post-delivery charges, outfitting costs, and costs of hull/mechanical/electrical plus growth. Construction costs are calculated as the sum of costs for each major Ship Work Breakdown Structure (SWBS) group. Principal data used by the CERs are weights categorized according to the SWBS and a series of user specified cost factors (K_N factors) that may be used to account for differing costs of technologies. Default K_N values were used for the baseline with the exception of structures (Group 100). Cost of the combat system was calculated by hand and treated as a user input. Derivation of

the Group 100 K_N factor and payload cost is contained in Appendix A.

The second type of cost that was estimated is Operating and Support (O&S) costs. Data used to compute O&S costs include average acquisition cost, number of accommodations, deferred maintenance manhours, fuel consumption rates, initial spares and repair parts, fuel cost, and service life.

It is important to note that if this was an acquisition baseline instead of a technology assessment baseline, cost would have been considered up front with the performance requirements. An acquistion baseline requires an analysis of the Ship Construction Navy (SCN) budget so that a a prediction of future allocation can be made. A design to cost figure can then be ascertained.

Table 17. ASW FRIGATE BASELINE DESIGN SUMMARY

1. Gross Characteristics

Length Between Perps	425.0 FT
Beam (On DWL)	50.0 FT
Draft (To DWL)	18.8 FT
Depth (Midship)	38.0 FT
Freeboard (At FP)	29.7 FT
Full Load Disp	5537 LT
Payload Weight	675.0 LT
Total Ship Vol	658118 FT^3
Metacentric Ht	4.83 FT
Prismatic Coeff	0.600
Max Section Coeff	0.803
Payload Fraction	0.122
Disp Lgth Ratio	72.1 LT/FT^3
Volumetric Density	18.8 LB/FT^3
LBP/B	8.50
B/T	2.66
LBP/D	11.2
GM_T/B	0.097
Roll Period (w/o fins)	10.0 SEC

2. Powering

Sustained Speed (Calm Water)	27.95 KT
Endurance Speed	20.00 KT
Range	4500 NM
Fuel Weight	865.0 LT
Endurance Power	9859 HP
PC at Endurance	0.747
Endurance SFC	0.544 LBM/HP-HR
Propeller Dia	16.2 FT
Max Propeller RPM	140.0

3. Ship Service

Propulsion Aux	267 KW
Avg 24 hr Load	2669 KW
Peak Elec Load	2841 KW

ASW FRIGATE BASELINE DESIGN SUMMARY (CONTINUED)

4. Weight Breakdown

SWBS	Group	Weight [LT]	% [FL]	VCG [FT]	LCG [FT]
100	Structure	1300.7	23.5	24.4	207.7
200	Propulsion	429.6	7.8	17.3	296.6
300	Electrical	248.4	4.5	23.5	242.3
400	Com + Surv	649.6	11.7	11.5	161.5
500	Auxiliary	634.6	11.5	23.9	233.8
600	Outfit	394.0	7.1	27.2	212.5
700	Armament	130.0	2.3	35.4	191.3
	Groups 1-7	3786.9	68.4	21.9	216.4
	Acq Wt Margin	473.3	8.5		
	Acq KG Margin			2.7	
Lightship Weight		4260.1	76.9	24.7	216.4
	Loads	1277.2	23.1	12.2	210.3
Full Load Weight		5573.3	100.0	21.8	215.0

5. Volume Breakdown

Hull Volume 550657 FT3
Deckhouse Volume 107462 FT3

SSCS	Group	Volume [FT3]	% VOL TOT
1.0	Mission	148288	22.5
2.0	Human Support	135750	20.6
3.0	Ship Support	196397	29.9
4.0	Ship Mobility	177384	27.0
5.0	Unassigned	299	00.0
Total Ship Volume		658118	100.0

ASW FRIGATE BASELINE DESIGN SUMMARY (CONTINUED)

6. Manning

Ship Manning	
Officers	17
CPO	16
Enlisted	198
Aviation Dept	
Officers	9
CPO	3
Enlisted	30
Accommodations	301

7. Margins[1]

Acq Weight	12.5%
Acq KG	12.5%
Space	0.0%
Acq Electrical	20.0%
Service Life Elect	20.8%
Propulsion Power	8.0%
Accommodations	10.0%
Strength	2.78 KSI

Note: (1) Consistent with CONFORM policy except for the space margin.

Figure 9. ASW FRIGATE BASELINE PROFILE

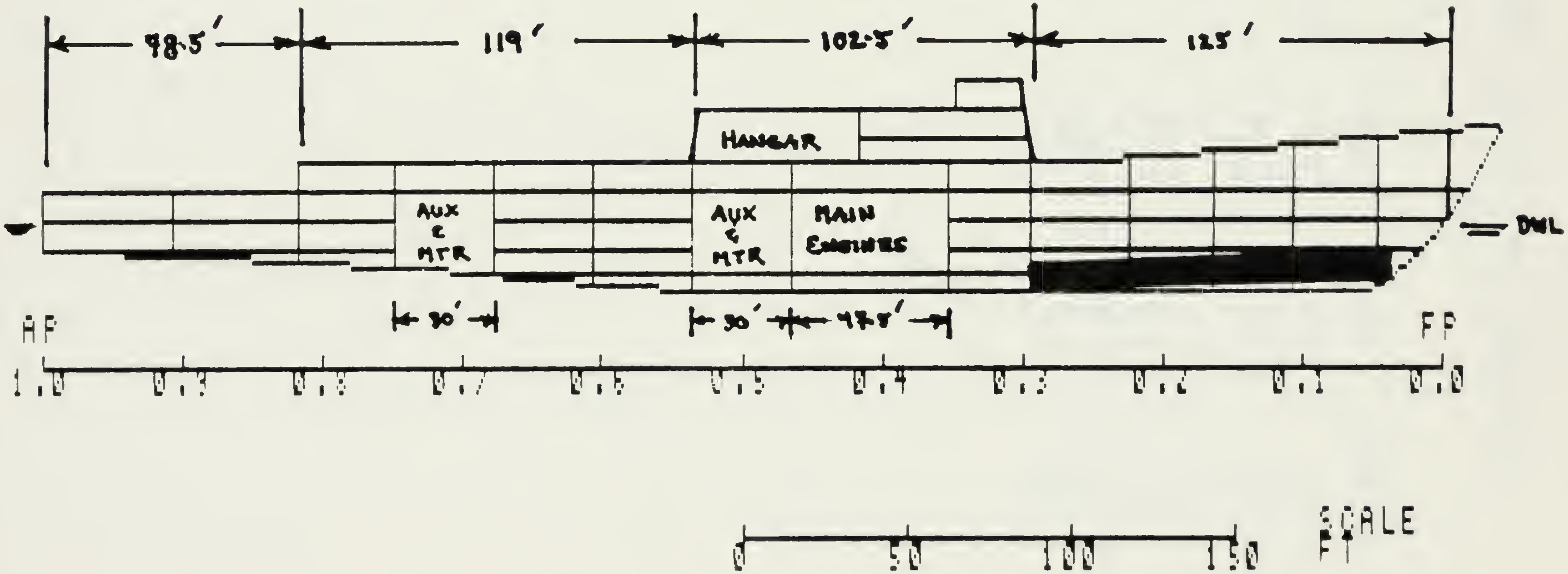


Table 18. ASW FRIGATE LARGE OBJECT SPACE REQUIREMENTS

Space Description	Length	Width	Height
Machinery Module (GT & Gen)	45.0	10.0	9.5
Propulsion Motor	13.0	12.5	12.5
Helo Hangar (per Helo)	50.0	20.0	15.0
Helo Folded Dimensions	41.0	11.0	13.5
Helo Operating Dimensions			
Tactical VLS (32 Cell)	18.0	24.0	24.0
VL Seasparrow (16 Cell)	14.5	12.5	17.0
76mm Gun	16.0	13.5	17.0
Towed Array Handling	35.0	35.0	8.5
Conformal Array	75.0	2.0	10.0
Transmit Array	30.0	2.0	10.0

Note: 76mm Gun requires 18 FT train circle.

Figure 10. ASW FRIGATE BASELINE DECK LAYOUT

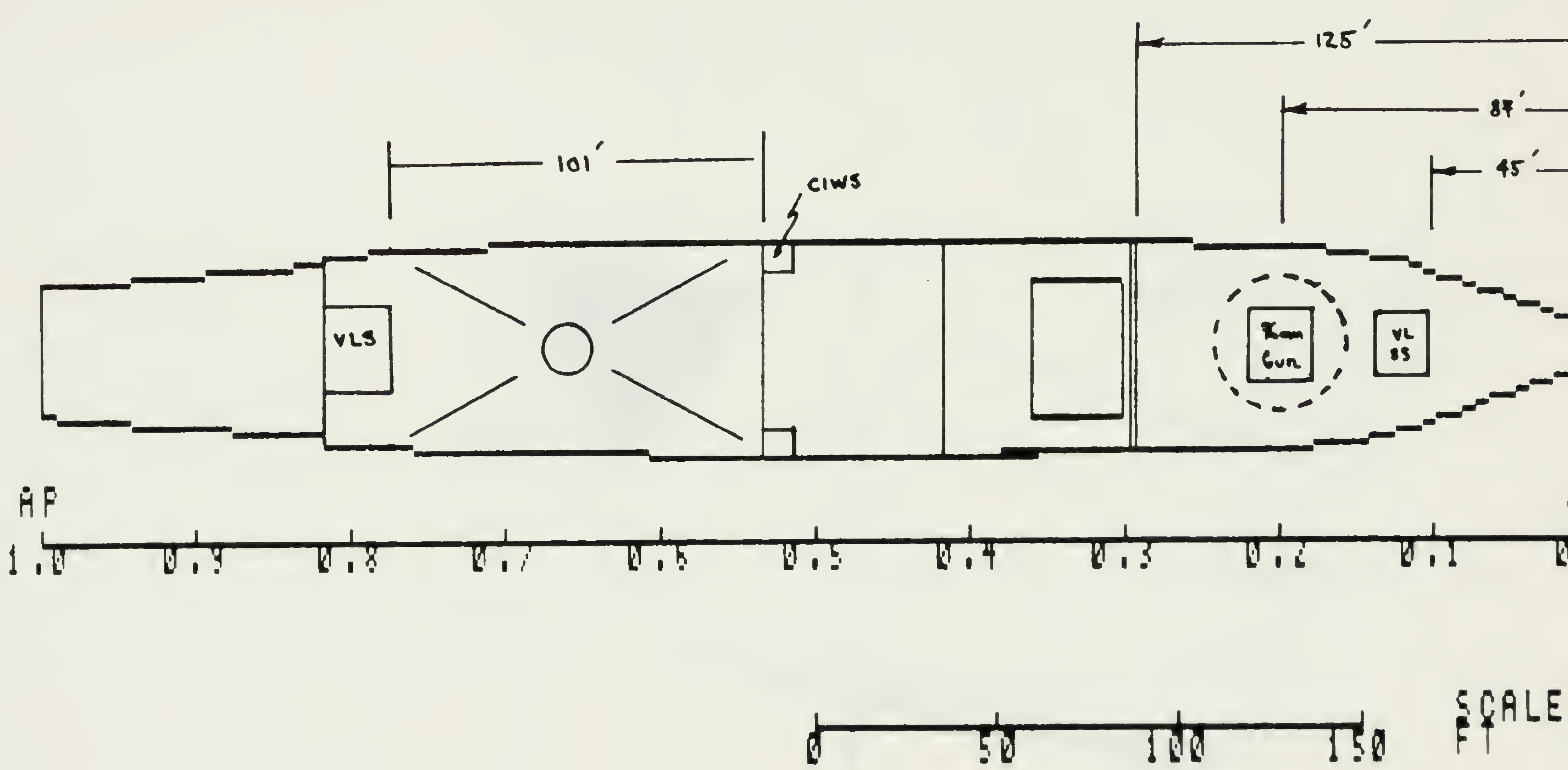


Figure 11. ASW FRIGATE BASELINE BODY PLAN

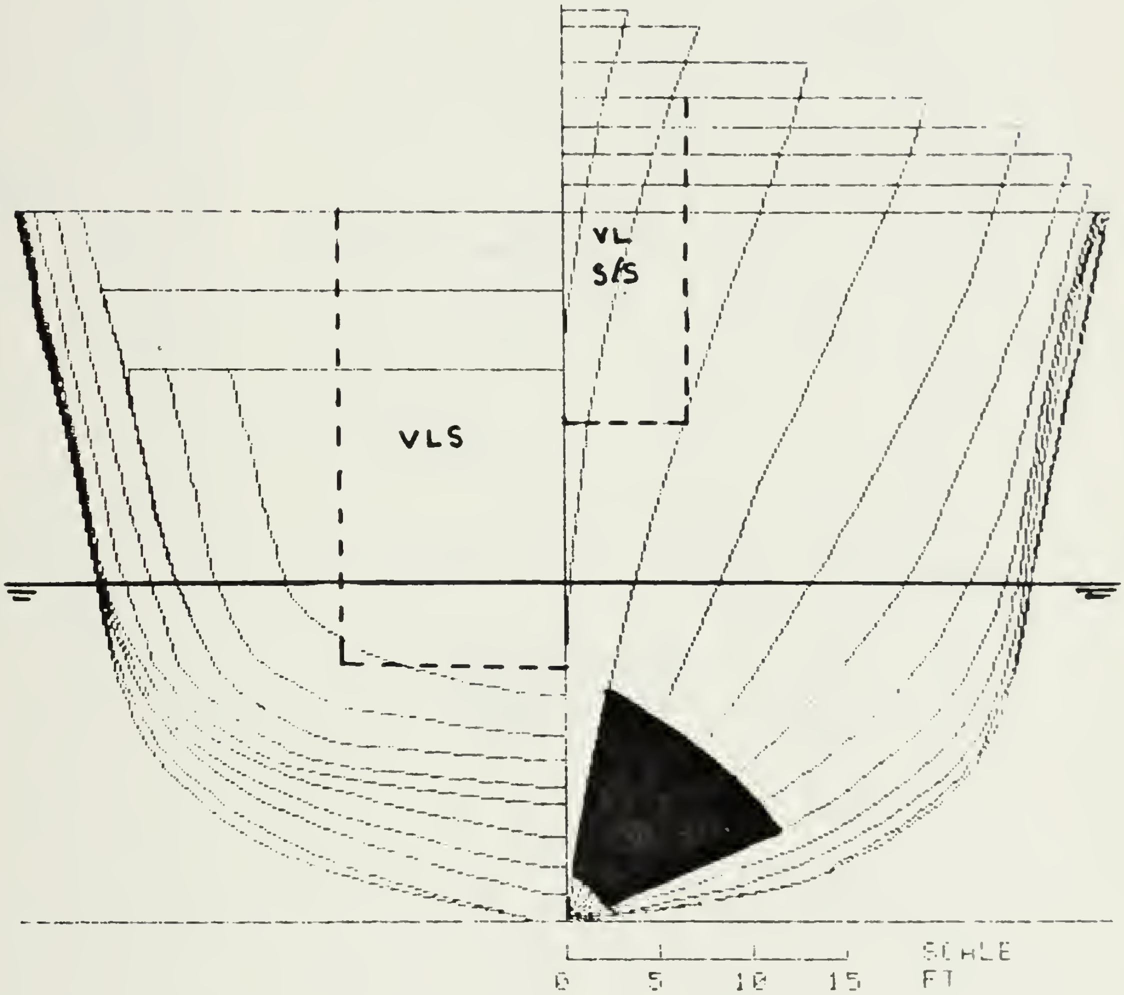
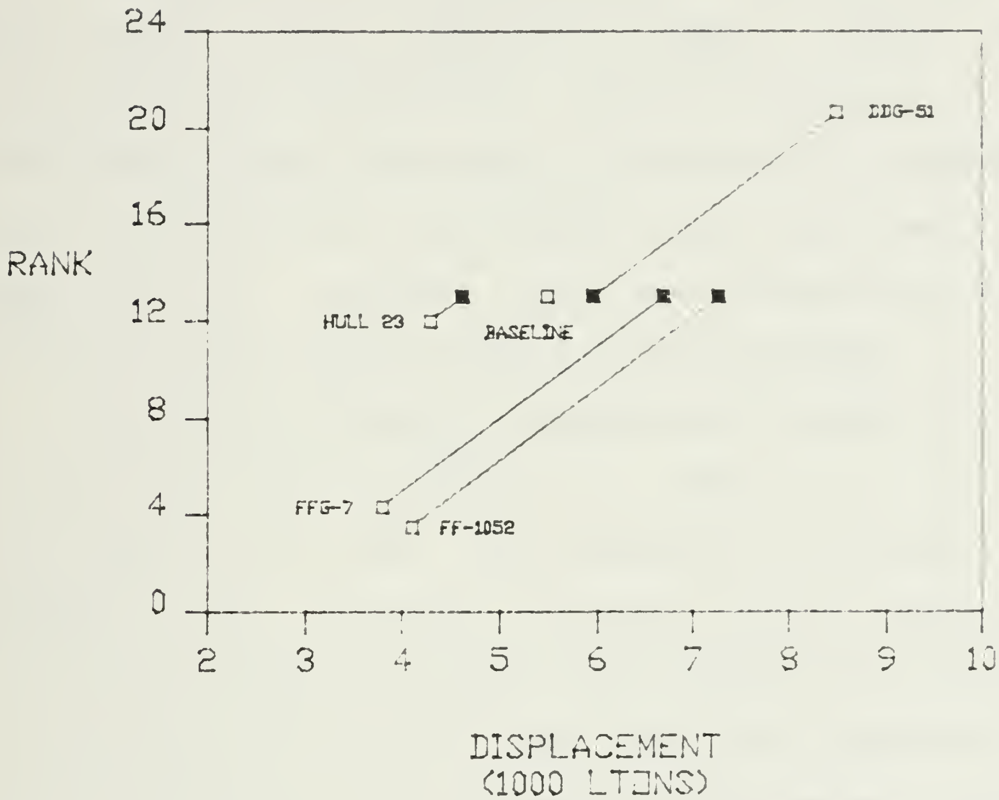


Figure 12. SEAKEEPING RANK COMPARISON



4.5 Technology Evaluation

The intent of this effort was to study a wide range of technologies for combatant ships, select the most representative, characterize them as accurately as possible, and perform impact analysis to determine the changes in ship size, configuration, performance, cost, and risk. The final step was to evaluate the most promising synergistic combination and incorporate it into the design.

A survey of potential technologies suitable for a frigate yielded the list presented in Table 19. The principal attributes which make the technologies attractive are also listed. This selection provided a nice sampling of the various functional areas for testing the proposed methodology. It is important to point out that this represents only a partial listing of the myriad of technologies suitable for a frigate.

Characterizations of each technology are contained in Appendix B. Information for the characterizations was obtained from open literature whenever possible. In general, the technical data represents a mean value from the various references.

Table 19. ATTRACTIVE TECHNOLOGIES FOR A FRIGATE

Containment

1. High Strength Low Alloy Steel (HSLA) Hull/Deckhouse
   - high strength coupled with low fabrication and material cost

2. NAVTRUSS Deckhouse
   - lightweight and fire safe

Propulsion

3. Intercooled/Regenerative Gas Turbine (IRGT)
   - reduced specific fuel consumption (SFC)

4. Contrarotating Propeller (CR)
   - high propulsive coefficient (PC)

Electrical

5. Propulsion Derived Ship Service (PDSS)
   - more efficient (improved combined SFC) and reduction in volume allocated to ship service

6. Rotary Engine Ship Service Generator (SSG)
   - reduced SFC

Outfit

7. Composite Masts and Topside Ladders
   - Weight and KG reduction

Detailed results of the impact analysis for each candidate technology are presented in Appendix C. The steps used to conduct the analysis using ASSET are outlined below.

(1) Enter data necessary to represent the important characteristics of the technology being evaluated. The adjustments made to the baseline Model Parameter List (MPL) are contained with the characterization sheets in Appendix B.

(2) Balance the design attempting to keep the performance the same. This was achieved by setting mission indicators as follows:

DESIGN MODE = ENDURANCE

DESIGN SPEED = CALC

ENDURANCE SPEED = GIVEN

Then the design was balanced as described below.

(a) Use DESIGN command to achieve a weight balance.

(b) Warp the hull to float at the design waterline by matching the draft given in the HYDROSTATIC ANALYSIS summary to the design waterline draft given in the DESIGN SUMMARY. This is achieved by having the HULL SIZE and HULL SHAPE indicators set to CALC and adjusting T/D.

(c) Adjust beam to get adequate stability if GM_T has been reduced below the baseline value. This is accomplished by adjusting **LBP/B** until the GM_T value given in the HYDROSTATIC ANALYSIS summary is sufficient.

(d) Obtain a space balance by matching the required and available volume. The recommended method for achieving the balance is:

1) bring in the beam if excess stability exists, since this will improve powering,

2) adjust length, and

3) possibly depth (as long as it is not being driven by large object space requirements).

For the impact studies conducted, there was an attempt to normalize GM_T and to meet or exceed the minimum freeboard requirement. The deckhouse volume was kept constant because any change in size would effect KG. A better method of balancing space is to compare large object space, deck area, and tankage volume to ensure there is adequate space. ASSET currently does not adequately support this method. However, a simple volume balance was considered sufficient for the purpose of this case study.

(3) Assemble data necessary to conduct evaluations. This requires information from the following modules: WEIGHT, SPACE ANALYSIS, HULL STRUCTURE, MACHINERY, PROPELLER, SEAKEEPING ANALYSIS, and COST ANALYSIS.

Once the ASSET results were tabulated, an assessment of technical risk was made concerning the replacement of the baseline component with the new technology following the guidance of section 2.4. In addition, the effect on performance in areas not addressed by ASSET were diScussed. For example, a shorter ship generally means less combat system arrangeability, and a more complex system generally results in reduced reliability and availability.

The procedure outlined above for conducting impact analysis was followed whenever practical. Any deviations are noted in the discussion of each evaluation. It is important to note that the procedure used is only one approach to performing impact analysis. The decision was made to balance space , but an equally reasonable approach would be to normalize speed and/or seakeeping by adjusting the size of the ship and accepting the excess volume, stability, etc..

The results of the evaluations are summarized and discussed in Tables 20 through 27. Detailed results of the impact analysis are given in Appendix C in terms of ship characteristics, performance, cost, and risk. The areas of significant impact are discussed and recommendations are made concerning areas for further investigation.

4.6 Technology Integration

Based on the results of the technology evaluations, the following technologies were selected as the most promising in terms of their impact on ship size, stability, and/or cost.

IRGT Main Engines

Propulsion Derived Ship Service

Rotary Engine SSG

Lightweight HSLA Deckhouse

Composite Masts and Topside Ladders

These can be categorized into two groups: fuel reducers and KG reducers. It was decided to pick one technology from each category to obtain a clear evaluation of a synergistic combination. The propulsion derived ship service was chosen over the rotary engine SSG and IRGT main engines because it offered the most fuel savings as well as direct savings in ship support volume. The HSLA deckhouse was preferred over the composite masts and topside ladders because of the greater reduction in KG. The impact of this integrated technology approach is presented in Table 28.

The results show the additional gains made by the proper combination of technologies. The key is to look for complementary technologies. In this case, the KG reduction allowed the beam to be brought in and the powering improved enough to partially offset the reduction in power available to propulsion because of the PDSS configuration. The

improvements show the potential gains from a good synergistic combination. Gains exceed the sum of the individual results in every area of significant impact. Note that the performance, measured in sustained speed and seakeeping rank factor, was significantly less degraded than when the PDSS was assessed individually. An interesting alternative approach would be to fix fuel weight and show the gain in endurance achievable.

Any comparison of between alternate ship configurations leads to inevitable questions regarding assumptions, procedures, and interpretation of the results. It was the aim of this study to validate a standard method for conducting technology impact evaluations. The proposed methodology is not a set of strict rules, but rather, some recommended guidelines. They were meant to assist the experienced designer in conducting technology impact evaluations and to provide a standard format for presenting the data to the decision makers. To this end, the methodolgy appears sound and is worthy implementation.

Table 20. DISCUSSION OF TECHNOLOGY IMPACT HSLA VS HTS HULL

1. Description of Tradeoff

HSLA material substituted for HTS in all primary hull structural members (deck / shell / bottom plating, longitudinal stringers and girders, web frames, deck beams, and watertight bulkheads).

2. Areas of Significant Impact

Displacement, KG, Acquisition Cost

3. Improvements (Variant vs Baseline)

Indice	Variant	Change	Diff%
Displacement [LT]	5477.1	-60.2	-1.1
W_{100} [LT]	1251.3	-49.4	-3.8
Full Load KG [FT]	21.63	-0.16	-0.7
GM_T [FT]	4.94	+0.11	+2.3

Reduction in displacement primarily due to 3.8% reduction in Group 100 weight. Decrease in KG due to lighter scantlings. The lower KG resulted in an increase in GM_T and allowed the beam to be reduced. A slight increase in ballistic protection occurred were plating thicknesses remained unchanged since ability to resist penetration is proportional to ultimate tensile strength.

4. Degradation (Variant vs Baseline)

Indice	Variant	Change	Diff%
Avg Acq Cost [$M]	566.1	+7.1	+1.3

Increase in acquisition cost due to 40% higher unburdened construction cost of HSLA. Slight increase in O&S costs due to method of estimating which includes acquisition cost as a factor.

5. Difficulties to Exploit Technology Fully

(a) Minimum thickness and standard size requirements resulted in an increase in stress margin, and hence, only a 3.8% reduction in weight was achieved.

(b) Volume requirements prohibited the beam from being reduced enough to normalize GM_T. An alternate approach was taken to increase length to gain volume and reduce the beam, but the overall impact was essentially the same because the improvement in powering was offset by the increased structural weight. Hence, need a reduction in required volume to take full advantage of the HSLA material.

6. Recommendation

Slight reduction in displacement and KG, and the increased ballistic protection does not offset higher material procurement and fabrication costs. Recommend not replacing HTS with HSLA on a global basis in the ASW Frigate's hull structure.

7. Areas for Further Investigation

(a) Explore isolated use for particular applications such as crack arressment, fragmentation protection, main deck plating, etc..

(b) Synergistic combination with a technology that reduces volume and would allow a reduction in beam.

Table 21. DISCUSSION OF TECHNOLOGY IMPACT HSLA VS HTS DECKHOUSE

1. Description of Tradeoff

HSLA material substituted for HTS in deckhouse structure (side plating, stiffeners, exterior and interior decks). Same 3 psi blast criteria.

2. Areas of Significant Impact

Displacement, KG

3. Improvements (Variant vs Baseline)

Indice	Variant	Change	Diff%
Displacement [LT]	5486.5	-50.8	-0.9
W_{150} [LT]	120.2	-36.3	-23.6
Full Load KG [FT]	21.42	-0.37	-1.7
GM_T [FT]	5.16	+0.33	+6.8

Reduction in displacement and decrease in KG primarily due to 23.6% reduction in Group 150 weight. The lower KG resulted in an increase in GM_T and allowed the beam to be reduced.

4. Degradation (Variant vs Baseline)

No significant degradation. Increased cost of HSLA was offset by reduction in weight.

5. Difficulties to Exploit Technology Fully

(a) Minimum thickness requirements/standard sizes make it difficult to achieve the lower structural density.

(b) Volume requirements prohibited the beam from being reduced further to normalize GM_T and improve powering.

6. Recommendation

A reduction in size without an appreciable change in cost is a noteworthy achievement. However, in this case it is suspect because of the questionable value for structural density. It is hard to believe that the change in deckhouse structural weight could approach the same order of magnitude as the change in hull weight achieved by changing to HSLA. Therefore it is recommended that a detailed structural design of the deckhouse be performed to ensure that the estimated weight reduction is achievable.

7. Areas for Further Investigation

(a) Consider increased fragmentation protection at the same weight as HTS.

(b) Synergistic combination with a technology that reduces volume and would allow a reduction in beam.

(3) Investigate tradeoff for 7 psi blast criteria. Addtional reduction in weight and KG should be avhievable since the minimum thickness requirement will be less of a factor.

Table 22. DISCUSSION OF TECHNOLOGY IMPACT NAVTRUSS VS HTS DECKHOUSE

1. Discussion of Tradeoff

NAVTRUSS panel structure was substituted for HTS in superstructure side plating and decks not subjected to concentrated loading. Same 3 psi blast criteria.

2. Areas of Significant Impact

Displacement, KG, Acquisition Cost

3. Improvements (Variant vs Baseline)

Indice	Variant	Change	Diff%
Displacement [LT]	5445.3	-92.0	-1.7
W_{150} [LT]	88.9	-67.6	-43.2
Full Load KG [FT]	21.09	-0.70	-3.2
GM_T [FT]	5.43	+0.60	+12.4

Reduction in displacement and decrease in KG primarily due to 43% reduction in Group 150 weight. The lower KG resulted in an increase in GM_T and allowed the beam to be reduced.

4. Degradation (Variant vs Baseline)

Indice	Variant	Change	Diff%
Avg Acq Cost [$M]	565.7	+6.7	+1.2
Technical Risk	Moderate	Increased	

Increase in acquisition cost is due to 6 fold increase in unburdened procurement and fabrication cost for NAVTRUSS. Slight increase in O&S costs due to method of estimating which includes acquisition cost as a factor. Risk is increased because of difficulties in fabrication (proper joining of panels) and unknown maintenance requirements.

DISCUSSION OF NAVTRUS VS HTS DECKHOUSE (CONTINUED)

5. Difficulties to Exploit Technology Fully

(a) Volume requirements prohibited the beam from being reduced further to normalize GM_T and improve powering.

6. Recommendation

Significant weight savings and KG reduction are accompanied by substantial cost and risk increase. NAVTRUSS is not recommended for use in the ASW Frigate.

7. Areas for Further Investigation

(a) Combined with KEVLAR it could increase ballistic protection for a given weight allocation.

(b) Synergistic combination with a technology that reduces volume and would allow a reduction in beam.

Table 23. DISCUSSION OF TECHNOLOGY IMPACT
IRGT VS LM-2500

1. Description of Tradeoff

Intercooled/Regenerative Gas Turbine (IRGT) substituted for LM-2500 main engines. Installed power remained constant.

2. Areas of Significant Impact

Displacement, Fuel Weight, Acquisition Cost, O&S Cost

3. Improvements (Variant vs Baseline)

Indice	Variant	Change	Diff%
LBP [FT]	420.5	-4.5	-1.0
Displacement [LT]	5363.4	-173.9	-3.1
Fuel Weight [LT]	676.3	-188.7	-21.8
SFC_E	0.372	-0.172	-31.6
Fuel Cons [NM/LT]	6.7	+1.5	+28.9
Total Volume [FT^3]	649785	-8333	-1.3
O&S Costs [$M]	1015.1	-24.8	-2.3
Energy Cost	90.1	-24.9	-21.7
IR Signature	Improved		

Reduction in fuel weight due to the improved SFC resulted in reductions in dispacement and tankage volume. The decrease in tankage volume more than compensated for the additional volume required by the intercooler and regenerator. Thus, total volume required was reduced and the ship was able to shrink. The 20 ton per engine increase was offset by the reduction in fuel weight and ship size. The significant decrease in operating costs is attributed to the lower fuel rate. The regenerator offers an improvement in IR signature without resulting to external cooling methods.

4. Degradation (Variant vs Baseline)

Indice	Variant	Change	Diff%
Full Load KG [FT]	21.93	+0.14	+0.6
Seakeeping Rank	12.68	-0.34	-2.6
Avg Acq Cost [$M]	561.6	+2.6	+0.8
Technical Risk	Moderate	Increased	
C.S. Arrangeability	Degraded		

Rise in KG, due to the reduction in fuel, required the beam to be increased slightly to maintain GM_T. Seakeeping decreased due to the decrease in ship size, and acquistion cost increased due to the increased cost of the IRGT main engines. Note that the $2.0M increase in main engine cost translates to about $2.6M in ship cost because of profit and overhead. Reduction in length, though desirable from a ship size standpoint, results in slightly less combat system arrangeability.

5. Difficulties to Exploit Technology Fully

(a) Stability requirements precluded the beam from being reduced to achieve a volume balance. As a result, length was decreased to achieve the volume balance and powering suffered because of the increase in LBP/B.

6. Recommendation

Economics (acquisition vs operating costs) are probably good enough to justify continued development. Need to tradeoff with other propulsion options to ascertain most promising configuration for this design.

7. Areas for Further Investigation

(a) Synergistic combination with a technology that reduces KG to allow a reduction in beam and an improvement in powering.

Table 24. DISCUSSION OF TECHNOLOGY IMPACT CR VS FP PROPELLERS

1. Desscription of Tradeoff

Contrarotating (CR) propellers were substituted for the two fixed pitch (FP) propellers.

2. Areas of Significant Impact

V_S, Acquisition Cost

3. Improvements (Variant vs Baseline)

Indice	Variant	Change	Diff%
Displacement [LT]	5530.9	-6.4	-0.1
Fuel Weight [LT]	861.9	-3.1	-0.4
SHP_E	9777	-82	-0.8
PC_E	0.800	+0.053	+7.1
PC_{DESIGN}	0.805	+0.087	+12.1
V_S [KT]	28.22	+0.27	+1.0

Increase of 7% in PC at endurance had little effect on SHP and hence fuel weight because of the 6% increase in total drag. The increase in sustained speed was achieved because of the proportionately larger difference in PC between the FP and CR configuration at the design condition due to the relatively flat efficiency curve of the CR propeller.

4. Degradation (Variant vs Baseline)

Indice	Variant	Change	Diff%
Total $Drag_E$ [LBS]	107644	+6264	+6.2
Avg Acq Cost [$M]	566.6	+7.6	+1.4
Technical Risk	MOD-HIGH	Increased	
Operability	Degraded		

The increase in drag was due to the higher appendage drag associated with the CR system. Acquisition cost increased because of the increased cost of the CR system. Slight increase in O&S costs can be attributed to increased acquisition cost. The apparent slight rize in KG is probably not accurate. The small reduction in fuel should have been offset by the increased propulsor and shafting weight. For the purpose of this analysis it can be ignored. The CR system represents much higher risk and reduced RM&A because of the increase complexity and number of components.

DISCUSSION OF CR VS FP PROPELLERS (CONTINUED)

5. Difficulties to Exploit Technology Fully

(a) Discrete engine size associated with gas turbine propulsion did no allow the installed shaft horsepower to be decreased in order to normalize V_s.

(b) Ship could not be shortened to normalize V_s because of volume requirements.

6. Recommendation

Slight change in sustained speed does not justify substantially higher cost and risk. Justified only if appendage drag can be lowered to improve fuel consumption and increase sustained speed significantly, or if acoustic characteristics are substantially better.

7. Areas for Further Investigation

(a) More accurate determination of appendage drag since current estimates negate improve PC.

(b) Investigate acoustic characteristics.

Table 25. DISCUSSION OF TECHNOLOGY IMPACT
PROPULSION DERIVED VS GT SHIP SERVICE

1. Description of Tradeoff

Two 2500 KW propulsion derived variable speed constant frequency generators and one 2500 KW gas turbine generator replaced four 1500 KW gas turbine generators.

2. Areas of Significant Impact

Displacement, Total Volume, Fuel Weight, V_B, $\hat{R}$, Acquisition Cost, O&S Cost

3. Improvements (Variant vs Baseline)

Indice	Variant	Change	Diff%
LBP [FT]	415.0	-10.0	-2.4
Beam	49.3	-0.70	-1.4
Draft	17.97	-0.80	-4.3
Depth	37.0	-1.00	-2.6
Displacement [LT]	5104.5	-432.8	-7.8
Total Volume [FT^3]	626785	-31333	-4.8
Fuel Weight [LT]	710.5	-155.5	-18.0
SL Elec Margin [KW]	1147	+506	+78.9
Avg Acq Cost [$M]	553.9	-5.1	-0.9
O&S Costs [$M]	1015.1	-24.8	-2.3

Reduction in volume, due to decrease in tankage and ship support volume requirements, allowed reduction in ship size which in turn produced second order reductions in volume requirements. The lower displacement was a result of reduced size, fuel requirements, and direct weight savings offered by the propulsion derived configuration. Fuel weight was decreased because of the improved efficiency of the integrated electrical plant. Service life electrical margin increased substantially because three generators were used. Lower acquisition cost was a result of reduced ship size. Reduction in O&S costs was due primarily to lower fuel rate.

DISCUSSION OF PROPULSION DERIVED VS GT SHIP SERVICE (CONT.)

4. Degradation (Variant vs Baseline)

Indice	Variant	Change	Diff%
V_B [KT]	27.16	-0.79	-2.8
Seakeeping Rank	12.01	-1.01	-7.8
Technical Risk	MOD-HIGH	Increased	
C.S. Arrangeability	Degraded		
Operability	Degraded		

Reduction in installed power available for propulsion because of the integrated configuration, along with a slightly less efficient hull form resulted in a loss in sustained speed. The lower seakeeping rank was due to the decrease in ship size. The 10 FT reduction in length to achieve a volume balance makes combat system arrangement more difficult. The complexity of the propulsion derived system impacts on RM&A and represents significant technical risk in the areas of power quality and equipment reliability.

5. Difficulties to Exploit Technology Fully

(a) It would have been better to consider a four generator arrangement with two 1500 KW standby units, but data was mainly available for a three generator configuration and ASSET currently considers only three generators when two main engines are used for propulsion. This produces some operational and survivability concerns (three vs four generators) as well as excessive service life margin due to USN generator sizing practices.

(b) Discrete GT engine size did not allow installed power to change in order to normalize V_B.

(c) Ship could not have been lengthened to normalize V_B without producing excess volume because of stability and freeboard requirements.

6. Recommendation

Propulsion derived ship service generators offer the opportunity to obtain substantial fuel savings (and the benefits in reduced ship size and cost associated with this reduction in fuel) over the exclusive use of dedicated gas turbine generator sets. The basic technology is in hand to develop such systems, and the calculated payoffs indicated a high rate of return would be realized on this investment.

7. Areas for Further Investigation

(a) Synergistic combination with a technology that reduces KG to allow a reduction in beam and an improvement in powering.

(b) Investigate a four generator configuration with two standby gas turbine units.

(c) The ship was balanced in volume by reducing LBP, beam, and depth while maintaining stability and freeboard. Another alternative is to keep V_s or seakeeping constant by adjusting length and allowing available volume to exceed required.

Table 26 DISCUSSION OF TECHNOLOGY IMPACT
ROTARY ENGINE VS GT SHIP SERVICE

1. Description of Tradeoff

Rotary engines were substituted for gas turbine prime movers on the four 1500 KW ship service generators.

2. Areas of Significant Impact

Displacement, Total Volume, Fuel Weight, Acquisition Cost, O&S Cost

3. Improvements (Variant vs Baseline)

Indice	Variant	Change	Diff%
LBP [FT]	421.0	-4.0	-0.9
Displacement [LT]	5379.7	-157.6	-2.9
Total Volume [FT^3]	649412	-8706	-1.3
Fuel Weight [LT]	715.7	-149.3	-17.3
Fuel Cons [NM/LT]	6.3	+1.1	+21.1
Avg Acq Cost [$M]	556.6	-2.4	-0.4
O&S Costs [$M]	1018.1	-21.8	-2.1
Energy Costs [$M]	95.3	-19.1	-17.1

Reduction in fuel was primarily responsible for the reduction in volume and displacement. Ship size was able to be reduced to a configuration that retained good powering characteristics, and hence, no loss in sustained speed occured. Group 600 weight increased because of additional hull insulation required to maintain radiated noise levels. The reduction in Group 500 weight can be attributed to the reduction in volume. The slight decrease in Group 100 weight was a result of the shorter length between perpendiculars. The lower acquisition cost is due to the decrease in ship size and the lower cost of the rotary engines.

4. Degradation (Variant vs Baseline)

Combat system arrangeability and seakeeping were slighly impaired by the reduction in ship size.

DISCUSSION OF ROTARY ENGINEVS GT SHIP SERVICE (CONTINUED)

5. Difficulties to Exploit Technology Fully

None noted.

6. Recommendation

Rotary Engine ship service generators offer the opportunity to obtain substantial fuel savings (and the benefits in reduced ship size and cost associated with this reduction in fuel) over gas turbine generator sets. Tradeoff with other promising machinery options to determine the best configuration for the design.

7. Areas for Further Investigation

(a) Obtain information on radiated noise levels and operability.

Table 27. DISCUSSION OF TECHNOLOGY IMPACT
COMPOSITE VS STEEL MASTS & TOPSIDE LADDERS

1. Discussion of Tradeoff

Composite materials substituted for steel in masts and topside ladders.

2. Areas of Significant Impact

KG

3. Improvements (Variant vs Baseline)

Indice	Variant	Change	DIFF%
Displacement [LT]	5530.1	-7.2	-0.1
Full Load KG [FT]	21.70	-0.09	-0.4
GM_T [FT]	4.94	+0.11	+2.3

Reduction in displacement and KG direct result of high vcg weight savings. Electromagnetic interference (EMI) may be improved.

4. Degradation (Variant vs Baseline)

None noted.

5. Difficulties to Exploit Technology Fully

None noted.

6. Recommendation

Composites make sense if stiffness can be achieved at a reasonable price.

7. Areas for Further Investigation

(a) Synergistic combination with a technology that reduces volume and would allow a reduction in beam.

Table 28. DISCUSSION OF INTEGRATED TECHNOLOGY IMPACT
PROPULSION DERIVED SHIP SERVICE & HSLA DECKHOUSE

1. Description of Tradeoff

Two 2500 KW propulsion derived variable speed constant frequency generators and one 2500 KW gas turbine generator replaced four 1500 KW gas turbine generators. HSLA material substituted for HTS in deckhouse structure.

2. Areas of Significant Impact

Displacement, Total Volume, Fuel Weight, V_s, $\hat{R}$,
Acquisition Cost, O&S Cost

3. Improvements (Variant vs Baseline)

Indice	Variant	Change	Diff%
Displacement [LT]	5048.2	-489.1	-8.8
Total Volume [FT^3]	625923	-32195	-4.9
Fuel Weight [LT]	701.4	-163.6	-18.9
Fuel Cons [NM/LT]	6.4	+1.2	+23.1
Avg Acq Cost [$M]	553.8	-5.2	-0.9
O&S Costs [$M]	1014.7	-25.2	-2.4
Energy Cost [$M]	94.2	-20.8	-18.1

4. Degradation (Variant vs Baseline)

Indice	Variant	Change	Diff%
V_s [KT]	27.44	-0.51	-1.8
Seakeeping Rank	12.21	-0.81	-6.2

5. Comparison (Integrated vs Individual)

Indice	HSLA DKHS	PDSS	SUM	INTEGR
Displacement [LT]	-50.8	-432.8	-483.6	-489.1
Total Volume [FT^3]	-535	-31333	-31868	-32195
Fuel Weight [LT]	-2.5	-155.5	-158.0	-163.6
V_s [KT]	+0.05	-0.79	-0.74	-0.51
Seakeeping Rank	-0.06	-1.01	-1.07	-0.81
Avg Acq Cost [$M]	+0.1	-5.1	-5.0	-5.2
O&S Costs [$M]	+3.1	-23.8	-20.7	-25.2

The results show the additional gains obtainable when technologies are used in a synergistic combination. The KG reduction offered by the HSLA deckhouse more than offset the rise in KG due to the reduced fuel load of the PDSS configuration. The reduction in tankage and ship support volume requirements allowed the beam to be brought in and hence the size reduction was able to result in a geometry more favorable to powering. The decrease in beam to achieve a volume balance also allowed the ships length to be retained closer to the baseline value and hence there was less degradation of combat system arrangeability and seakeeping.

6. Recommendation

Recommend addtional integrated assessments to determine the most effective combination of subsystems for the design. The key is to look for synergistic relations that will enable the technologies to compliment each other in a beneficial manner.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this thesis was to develop a methodology for the assessment of HM&E technologies to assist ship designers and R&D Managers in determining which technologies should be funded for development.

A methodology was proposed and efforts were directed toward three major areas:

(1) technology information management,

(2) development of a proper baseline ship for ship impact assessment, and

(3) technology impact evaluations when performance is held constant.

Requirements were established for the management and coordination of technology information. The basic steps necessary to establish a good technology assessment baseline ship were presented. In addition, a process was developed for conducting technology impact evaluations when the performance is held constant. A case study was conducted for an ASW Frigate to validate the proposed methodology.

The proposed methodology should not be construed as a "cook book" approach, but rather a set of guidelines to assist in conducting HM&E impact analysis. It is important to have a rational thought process for assessing technologies. It is recognized that the decision to incorporate an innovation is heavily influenced by polictical considerations [9]. This reality emphasizes the need for an objective evaluation based

on sound engineering practice to serve as input to the final decision making process.

The need for early stage design tools to evaluate performance and mission effectiveness was highlighted. The design community essentially knows how to do impact analysis normalizing performance, but this does not capture the attention of ship operators. Operators desire increased performance, not necessarily reduced size and/or cost. This indicates that evaluations should probably be conducted both ways. Hence, the development of adequate early design tools to evaluate performance is a worthwhile project.

The following steps are recommended to adequately manage and coordinate the identification and assessment of new technology applicable to naval ships.

(1) Establish a single navy agent as the central clearing house for HM&E technologies applicable to naval ships. Another single agent should be designated for combat system technologies. These agents must be closely aligned.

(2) Characterize the data for the emerging technologies in a format similar to that proposed in Section 2.2.

(3) Implement a program for a continuously developing set of baseline ships following the guidelines established in Section 2.3 for determining the ship impact of these emerging technologies.

(4) Conduct impact evaluations following the procedure outlined in Section 2.4.

(5) Establish and maintain a new technology database.

(6) Publish a new technology catalog on an annual basis.

(7) Implement feedback mechanisms for influencing R&D resource allocations.

(8) Develop early stage design tools for the evaluation of performance changes and mission effectiveness.

(9) Develop improved risk assessment methods.

(10) Develop a methodology for conducting technology evaluations when size/cost is held constant and performance is allowed to change.

The primary goal of the proposed technology assessment program is to improve communication between ship operators, ship designers, and the R&D community (navy and industry). The program will not be successful unless we establish a design philosophy to consistently evaluate these emerging technologies. This will provide long term direction to our R&D establishment and result in a better product at sea.

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APPENDIX A

BASELINE ASW FRIGATE DATA

BASELINE MODEL PARAMETER LIST

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ADVANCED SURFACE SHIP EVALUATION TOOL (ASSET)
MONOHULL SURFACE COMBATANT MODEL (MONOSC)



PLEASE ENTER DATA BANK FILE SPECIFICATION.

C,E>SHIPS
SHIPS CURRENTLY IN DATA BANK-
     BASELINE.BACKUP          BASELINE.TROOST        BASELINE
     IRGT                     HSLA HULL              HSLA DKHS
     NAVTRUSS                 CR PROP                COMPOSITES
     WANKEL SSG               PROP DERIVED SSG       INTEGRATED TECH

C,E>

C,E>

C,E>USE,BASELINE

C,E>TERMINAL OUTPUT=OFF

C,E>CURRENT MODEL
SHIP REQ
  MISSION
     DESIGN MODE IND        = ENDURANCE
     ENDURANCE              =  4500.00
     DESIGN SPEED IND       = CALC
     DESIGN SPEED           =  27.9496
     ENDURANCE SPEED IND    = GIVEN
     ENDURANCE SPEED        =  20.0000
  PAYLOAD
     PAYLOAD NAME TBL     (50X 4) =
  1 COMMAND AND CONTROL
  2 EXTERIOR COMMS
  3 SURFACE SEARCH AND IFF
  4 NAVIGATION RADAR
  5 IR DETECTOR
  6 TOWED ARRAY
  7 ASW ELECTRONICS
  8 ACTIVE ECM
  9 ACOUSTIC DECOY
 10 MK-92 FCS
 11 76MM GUN
 12 TWO CIWS
 13 32 CELL VLS
 14 16 CELL VL SEASPARROW
 15 SRBOC
 16 MK-32 SVTT
 17 76MM AMMO
 18 12000 RDS 20MM AMMO
 19 32 ASROC/HARPOON
 20 16 SEASPARROW
 21 2 RSL SRBOC
 22 TORPEDOES IN TUBES
 23 THREE LAMPS III
 24 LAMPS HANDLING AND STOWAGE
 25 LAMPS SUPPORT
 26 LAMPS JP-5
```

```
27 LAMPS TORPEDOES
28 SONOBUOYS
    PAYLOAD WT KEY TBL  (50X 1) =
 1 W410
 2 W440
 3 W450
 4 W450
 5 W450
 6 W460
 7 W460
 8 W470
 9 W470
10 W480
11 W710
12 W710
13 W720
14 W720
15 W720
16 W750
17 WF21
18 WF21
19 WF21
20 WF21
21 WF21
22 WF21
23 WF23
24 W588
25 WF26
26 WF42
27 WF22
28 WF26
    PAYLOAD WT ARRAY    (50X 1) = LTON
 1  9.700
 2  14.30
 3  4.800
 4 0.1000
 5  1.000
 6  50.00
 7  90.00
 8  3.500
 9  2.300
10  5.000
11  34.90
12  11.00
13  64.50
14  11.50
15  2.200
16  4.000
17  6.600
18  9.200
19  55.00
20  3.900
21  2.400
22  1.400
23  26.70
24  15.00
25  12.00
26  95.00
27  12.00
28  12.00
```

```
    PAYLOAD KG KEY TBL  (50X 1) =
 1 D10
 2 D10
 3 D10
 4 D10
 5 D10
 6 D20
 7 D6.5
 8 D10
 9 D20
10 D10
11 D6.5
12 D10
13 D15
14 D3
15 D10
16 D10
17 D6.5
18 D10
19 D15
20 D3
21 D10
22 D10
23 D10
24 D15
25 D10
26 BL
27 D10
28 D10
    PAYLOAD KG ARRAY    (50X 1) = FT
 1 -21.00
 2 -21.00
 3  20.00
 4  12.00
 5  12.00
 6 -4.500
 7 -29.50
 8  20.00
 9 -6.500
10  20.00
11  4.000
12  21.00
13 -11.00
14 -8.000
15  19.00
16  3.000
17 -4.500
18  12.50
19 -11.00
20 -8.000
21  19.00
22  4.000
23  5.000
24 -4.000
25 -6.000
26  9.000
27  4.000
28  4.000
    PAYLOAD AREA KEY TBL(50X 1) =
 1 A1131
```

```
 2 A1111
 3 A1121
 4 NONE
 5 A1121
 6 A1122
 7 A1122
 8 A1141
 9 A1142
10 A1121
11 A1210
12 NONE
13 A1220
14 A1220
15 NONE
16 NONE
17 NONE
18 A1210
19 NONE
20 NONE
21 NONE
22 NONE
23 NONE
24 A1340
25 A1390
26 NONE
27 A1374
28 A1390
    PAYLOAD AREA ARRAY   (50X 2) = FT2
 1  1400.       0.0000E+00
 2  540.0       0.0000E+00
 3 0.0000E+00   40.00
 4 0.0000E+00 0.0000E+00
 5 0.0000E+00   40.00
 6  1200.       0.0000E+00
 7  1800.       0.0000E+00
 8 0.0000E+00   200.0
 9  185.0       0.0000E+00
10 0.0000E+00   320.0
11  432.0       0.0000E+00
12 0.0000E+00 0.0000E+00
13  1296.       0.0000E+00
14  362.0       0.0000E+00
15 0.0000E+00 0.0000E+00
16 0.0000E+00 0.0000E+00
17 0.0000E+00 0.0000E+00
18 0.0000E+00   144.0
19 0.0000E+00 0.0000E+00
20 0.0000E+00 0.0000E+00
21 0.0000E+00 0.0000E+00
22 0.0000E+00 0.0000E+00
23 0.0000E+00 0.0000E+00
24  300.0       6000.
25  240.0       360.0
26 0.0000E+00 0.0000E+00
27 0.0000E+00   533.0
28 0.0000E+00   267.0
    PAYLOAD KW ARRAY     (50X 2) =
 1  35.00       67.00
 2  7.000       18.00
 3 0.6000      0.4000
```

```
 4 0.0000E+00 0.0000E+00
 5 0.0000E+00 0.0000E+00
 6 0.0000E+00 0.0000E+00
 7 0.0000E+00 0.0000E+00
 8  5.000       40.00
 9  1.700      0.0000E+00
10  14.60       9.100
11  8.000       20.00
12  11.00       14.00
13  108.2      0.0000E+00
14  35.10      0.0000E+00
15 0.8000      0.6000
16  11.80      0.0000E+00
17 0.0000E+00 0.0000E+00
18 0.0000E+00 0.0000E+00
19 0.0000E+00 0.0000E+00
20 0.0000E+00 0.0000E+00
21 0.0000E+00 0.0000E+00
22 0.0000E+00 0.0000E+00
23 0.0000E+00 0.0000E+00
24  28.00      0.0000E+00
25  2.000       3.000
26 0.0000E+00 0.0000E+00
27 0.0000E+00 0.0000E+00
28 0.0000E+00 0.0000E+00
HULL
  HULL FORM GEOMETRY
    HULL SIZE IND          = CALC
    LBP                    =  425.000      FT
    HULL SHAPE IND         = CALC
    LBP/B                  =  8.50000
    LBP/D                  =  11.1840
    T/D                    = 0.493400
    LCB/LBP                = 0.503038
    PRISMATIC COEF         = 0.600000
    MAX SECTION COEF       = 0.803000
    HULL VOLUME            =  550657.      FT3
  HULL OFFSETS
    STATION ARRAY          (25X 1) = FT
 1 -17.30
 2 -7.688
 3  4.427
 4  21.54
 5  39.43
 6  58.11
 7  77.58
 8  101.6
 9  123.6
10  139.0
11  159.0
12  178.0
13  205.0
14  216.5
15  228.9
16  256.0
17  271.0
18  291.3
19  305.9
20  323.5
21  3[illegible].5
```

22	346.6
23	346.6
24	374.0
25	425.0

HALF BEAM ARRAY (25X11) = FT

1	0.3337E-02	0.3337E-02	0.3337E-02			
2	0.3337E-02	1.101	3.600			
3	0.3337E-02	2.236	7.400			
4	0.3337E-02	5.273	9.724	11.01	13.18	
5	0.3337E-02	5.740	10.35	13.18	15.65	17.12
	19.51					
6	0.3337E-02	8.177	14.18	18.42	21.53	22.59
	24.51					
7	0.3337E-02	7.709	13.85	17.52	20.56	22.86
	24.80	25.70	27.13			
8	0.3337E-02	7.509	13.72	17.89	21.16	23.26
	24.36	25.46	26.27	27.03	28.11	
9	0.3337E-02	7.743	14.18	19.19	22.59	24.20
	25.16	26.83	28.37			
10	0.3337E-02	10.01	16.69	20.01	22.18	23.26
	23.94	24.81	25.53	27.09	28.62	
11	0.3337E-02	6.675	12.82	18.52	22.36	23.86
	24.56	25.83	27.40	28.17	28.87	
12	0.3338E-02	7.843	14.52	19.62	22.43	23.87
	24.60	26.07	27.54	28.31	29.00	
13	0.3338E-02	7.843	14.52	20.03	22.66	24.06
	24.69	26.20	27.74	28.45	29.11	
14	1.068	10.01	16.69	20.69	22.79	24.03
	24.69	26.23	27.77	28.47	29.13	
15	1.068	9.545	15.12	20.03	22.29	23.80
	24.56	26.07	27.64	28.35	29.00	
16	1.068	10.01	16.69	20.03	22.36	24.03
	25.16	26.00	27.54	28.25	28.90	
17	1.068	10.01	16.69	20.03	22.36	23.70
	25.13	25.87	27.37	28.10	28.75	
18	1.068	10.01	16.69	20.03	22.16	24.03
	24.96	25.73	27.30	28.05	28.70	
19	1.068	10.01	16.69	20.24	22.30	23.39
	24.29	25.58	26.51	27.32	28.09	
20	1.020	9.282	15.10	18.90	21.00	22.00
	23.19	24.14	25.36	26.23	27.03	
21	1.068	6.675	13.35	16.17	18.60	20.22
	21.54	22.86	23.78	24.79	25.71	
22	1.068	6.675	13.35	16.17	18.60	20.22
	21.54	22.86	23.65	24.15	24.57	
23	1.068	6.675	13.35	16.17	18.60	20.22
	21.54	22.70	23.20			
24	1.068	6.675	12.35	14.61	16.71	18.41
	19.31	20.41	21.20			
25	1.068	5.340	10.58	13.35	15.02	15.52
	16.07	17.17	17.82			

WATERLINE ARRAY (25X11) = FT

1	48.46	48.48	49.50			
2	30.49	38.12	48.80			
3	13.05	30.99	48.00			
4	0.1000	23.20	35.99	39.24	46.00	
5	0.0000E+00	12.57	23.09	28.93	34.58	37.64
	44.20					
6	0.0000E+00	10.59	19.75	27.39	33.74	36.79
	42.50					

```
 7 0.0000E+00  6.505     12.53     17.24     22.92     28.62
    33.29      36.37     41.00
 8 0.0000E+00  4.384     8.568     12.52     17.22     21.95
    25.84      30.21     33.10     36.07     39.50
 9 0.0000E+00  3.087     6.502     10.57     15.50     20.81
    25.52      32.97     38.00
10 0.0000E+00  3.087     6.501     9.158     12.14     14.71
    17.21      21.84     25.79     32.93     38.00
11 0.0000E+00  1.289     3.304     6.501     10.57     14.76
    18.48      25.79     32.93     35.97     38.00
12 0.0000E+00  1.112     3.217     6.487     9.803     13.52
    16.93      24.95     31.23     34.78     38.00
13 0.0000E+00  1.112     2.955     6.486     9.801     13.51
    16.93      24.93     31.19     34.67     38.00
14 0.0000E+00  1.951     4.379     7.516     10.50     13.76
    16.93      24.94     31.21     34.68     38.00
15 0.0000E+00  2.213     4.379     7.721     10.50     13.84
    16.93      24.94     31.21     34.68     38.00
16  1.530      3.997     6.745     9.144     11.98     15.68
    20.76      24.85     31.20     34.68     38.00
17  2.957      5.125     7.624     9.748     12.54     15.35
    20.57      24.76     31.19     34.67     38.00
18  4.572      6.433     8.596     10.61     13.02     16.79
    20.35      24.65     31.17     34.67     38.00
19  6.249      7.361     9.240     11.73     14.98     17.94
    21.54      27.14     31.15     34.67     38.00
20  7.205      8.018     9.350     11.90     14.74     17.95
    22.06      25.99     31.07     34.66     38.00
21  8.700      9.050     9.921     11.47     13.61     16.90
    21.17      26.92     30.94     34.66     38.00
22  8.700      9.049     9.921     11.46     13.59     16.85
    21.04      26.63     30.49     32.17     33.75
23  8.700      9.049     9.921     11.45     13.56     16.78
    20.85      26.22     29.50
24  10.00      10.70     11.54     12.84     14.38     17.55
    21.28      26.17     29.50
25  12.10      12.90     14.42     16.08     18.43     20.23
    22.43      26.93     29.50
  BILGE
    BILGE LOC IND         = CALC
    BILGE LOC ARRAY      (25X 1) =
 1 0.2000
 2 0.2000
 3 0.2000
 4 0.2000
 5 0.2000
 6 0.2000
 7 0.2000
 8 0.2000
 9 0.2000
10 0.2000
11 0.2000
12 0.2000
13 0.2000
14 0.2000
15 0.2000
16 0.2000
17 0.2000
18 0.2000
19 0.2000
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20 0.2000
21 0.2000
22 0.2000
23 0.2000
24 0.2000
25 0.2000
    BILGE KEEL IND        = NONE
  MARGIN LINE
    MARGIN LINE IND       = CALC
    MIN FREEBOARD MARGIN = 0.250000      FT
    MARGIN LINE HT ARRAY(25X 1) = FT
 1  49.25
 2  48.55
 3  47.75
 4  45.75
 5  43.95
 6  42.25
 7  40.75
 8  39.25
 9  37.75
10  37.75
11  37.75
12  37.75
13  37.75
14  37.75
15  37.75
16  37.75
17  37.75
18  37.75
19  37.75
20  37.75
21  37.75
22  33.50
23  29.25
24  29.25
25  29.25
  HULL SUBDIVISION
    HULL SUBDIV IND       = GIVEN
    TRANS BHD SPACING     = 0.100000E+37
    TRANS BHD LOC ARRAY (16X 1) =
 1 0.4710E-01
 2 0.1059
 3 0.1647
 4 0.2235
 5 0.2941
 6 0.3529
 7 0.4647
 8 0.5353
 9 0.6059
10 0.6765
11 0.7471
12 0.8153
13 0.9059
    HULL AVG DECK HT      =  8.50014     FT
    HULL DECK LOC ARRAY ( 4X 1) = FT
 1  29.50
 2  21.00
 3  12.50
 4  4.000
    HULL DECK CONT ARRAY( 4X17) =
```

```
1  1.000      1.000      1.000      1.000      1.000      1.000
   1.000      1.000      1.000      1.000      1.000      1.000
  0.0000E+00 0.0000E+00
2  1.000      1.000      1.000      1.000      1.000      1.000
  0.0000E+00 0.0000E+00  1.000      1.000    0.0000E+00  1.000
   1.000      1.000
3  1.000      1.000      1.000      1.000      1.000      1.000
  0.0000E+00 0.0000E+00  1.000      1.000    0.0000E+00  1.000
   1.000      1.000
4  1.000      1.000      1.000      1.000      1.000      1.000
   1.000      1.000      1.000      1.000    0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00
 HULL GIRDERS
   GDR INPUT IND        = CALC
   GDR LOC ARRAY        ( 3X 2) =
1 0.0000E+00 0.6000
2 0.0000E+00 0.6000
3 0.0000E+00 0.6000
 HULL MATERIALS
   HULL MTRL TYPE IND   = HTS
   HULL MTRL DENSITY    =  489.024     LBM/FT3
   HULL MOD OF ELAS     =  29600.0     KSI
   HULL YIELD STRENGTH  =  45.0000     KSI
   HULL PROPORTNL LIMIT =  34.0000     KSI
   HULL MAX PRIM STRESS =  21.2800     KSI
   HULL ALW WORK STRESS =  38.0000     KSI
   HULL POISSONS RATIO  = 0.300000
   C COEF ARRAY         ( 3X 1) =
1  400.0
2  630.0
3  800.0
   HULL MARGINAL STRESS =  2.24000     KSI
 HULL LOADS
   HULL LOADS IND       = CALC
   DES BOT PRESS ARRAY ( 3X 1) = LBF/IN2
1  19.23
2  16.98
3  14.20
   DES SIDE PRESS ARRAY( 3X 1) = LBF/IN2
1  17.49
2  8.533
3  7.298
   DES DECK PRESS ARRAY( 3X 1) = LBF/IN2
1  5.333
2  1.778
3  1.778
   INT DECK PRESS ARRAY( 4X 1) = LBF/IN2
1  1.042
2  1.042
3  1.042
4  1.042
   HOGGING BM           =  85086.1     FT-LTON/IN
   SAGGING BM           =  70936.1     FT-LTON/IN
   SHOCK FOUNDATION IND = SHOCK
 HULL STRUCTURE
   BOT STRING SPACING   =  20.0000     IN
   SIDE STRING SPACING  =  20.0000     IN
   DECK STRING SPACING  =  20.0000     IN
   FRAME SPACING        =  4.00000     FT
   BOT GDR AREA ARRAY  ( 2X 1) = IN2
```

```
1  16.88
2  16.51
   DECK GDR AREA ARRAY ( 2X 1) = IN2
1  7.621
2  7.621
   FRAME AREA ARRAY    ( 3X 1) = IN2
1  5.175
2  4.327
3  5.574
   DECK BEAM AREA ARRAY( 3X 1) = IN2
1  4.472
2  1.978
3  1.843
   LWR BEAM AREA ARRAY ( 4X 1) = IN2
1  1.305
2  1.248
3  1.122
4  1.060
   LWR GDR AREA ARRAY  ( 4X 2) = IN2
1  4.258       4.258
2  2.330       2.330
3  4.258       4.258
4  6.963       6.963
   LWR SKIN THICK ARRAY( 4X 1) = IN
1 0.2202
2 0.1577
3 0.2202
4 0.2827
   BHD SKIN THICK ARRAY( 5X 1) = IN
1 0.2300
2 0.2509
3 0.2609
4 0.2826
5 0.3713
   AVG SKIN THICK ARRAY( 3X 3) = IN
1 0.3795      0.3296      0.3608
2 0.3795      0.3296      0.3608
3 0.3795      0.3296      0.3608
   MIDSHIP MOI             =  211130.     FT2-IN2
 DKHS GEOMETRY
   DKHS LOC ARRAY      (20X 1) =
1 0.2941
2 0.4176
3 0.2976
4 0.3012
   DKHS SIDE DIM ARRAY (20X 2) = FT
1 0.0000E+00 0.0000E+00
2 0.0000E+00 0.0000E+00
3 0.0000E+00 0.0000E+00
4  10.00       10.00
   DKHS HT ARRAY       (20X 1) = FT
1  8.500
2  17.00
3  8.500
4  8.500
   DKHS LENGTH ARRAY   (20X 1) =
1 0.1235
2 0.1170
3 0.1200
4 0.5880E-01
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```
   WIND AREA FAC ARRAY ( 2X 1) =
1  1.250
2  1.250
   DKHS VOLUME            =  107462.      FT3
   DKHS VOLUME FRAC       = 0.195152
  DKHS MATERIALS
   DKHS MTRL TYPE IND     = HTS
   DKHS STRUCT DENSITY    =  4.18000      LBM/FT3
   FIRE PROTECTION IND    = NONE
PROPULSION PLANT
  MAIN ENGINE
   MAIN ENG SIZE IND      = GIVEN
   MAIN NO ENG            =  2.00000
   MAIN ENG TYPE IND      = GT
   MAIN CONT PWR AVAIL    =  26250.0      HP
   MAIN CONT RPM          =  3600.00
   MAIN ENG SFC           = 0.410000      LBM/HP-HR
   MAIN ENG SPEC WT       =  1.99000      LBM/HP
   MAIN CONT PWR REQ      =  21004.5      HP
   MAIN PWR MARGIN FAC    =  1.25000
  SEC ENGINE
   SEC ENG SIZE IND       =
   SEC NO ENG             = 0.100000E+37
   SEC ENG TYPE IND       = NONE
   SEC CONT PWR AVAIL     = 0.100000E+37 HP
   SEC CONT RPM           = 0.100000E+37
   SEC ENG SFC            = 0.100000E+37 LBM/HP-HR
   SEC ENG SPEC WT        = 0.100000E+37 LBM/HP
   SEC CONT PWR REQ       = 0.100000E+37 HP
   SEC PWR MARGIN FAC     = 0.100000E+37
  TRANSMISSION
   TRANS EFF IND          = CALC
   TRANS TYPE IND         = AC/AC
   DESIGN TRANS EFF       = 0.945000
   ENDURANCE TRANS EFF    = 0.930000
   GEAR K FAC             = 0.100000E+37 LBF/IN2
  MACHINERY ROOM
   MACHY BOX VOL IND      = CALC
   MACHY BOX VOL ARRAY ( 2X 1) =
1 0.1256E+06
2 0.0000E+00
   MAIN ENG CG IND        = CALC
   MAIN ENG CG ARRAY    ( 2X 1) =
1 0.5700
2 0.5600
   SEC ENG CG IND         = CALC
   SEC ENG CG ARRAY     ( 2X 1) =
1 0.1000E+37
  POWERING
   NO PROP SHAFTS         =  2.00000
   THRUST DED COEF        = 0.106500
   TAYLOR WAKE FRAC       = 0.665000E-01
   REL ROTATE EFF         =  1.00000
   DESIGN DHP             =  19849.7      HP
   ENDURANCE DHP          =  4167.58      HP
  PROPELLER
   PROP TYPE IND          = FP
   PROP METHOD IND        = ANALYTIC
   PROP DIA IND           = CALC
   PROP DIA               =  16.2082      FT
```

```
   PROP AREA IND          = CALC
   EXPAND AREA RATIO      = 0.682824
   BACK CAV ALLOWED       =  10.0000
   NO BLADES              =  5.00000
   PITCH RATIO            =  1.43665
   DESIGN PROP RPM        =  140.000
   ENDURANCE PROP RPM     =  90.2968
   PROP RPM LIMIT ARRAY( 2X 1) =
 1  140.0
 2  180.0
   PROP LOC IND           = CALC
   PROP LOC ARRAY        ( 2X 1) =
 1 0.9497
 2 0.5189E-01
   PROP SYS DISP IND      = CALC
   PROP SYS DISP          =  38.9298      LTON
   PROP SYS CB ARRAY     ( 3X 1) = FT
 1  383.5
 2  12.16
 3  1.972
  OPEN WATER PROP DATA
   PROP ID IND            =
   ADVANCE COEF ARRAY    (10X 1) =
 1 0.4500
 2 0.5500
 3 0.6500
 4 0.7500
 5 0.8500
 6 0.9500
 7  1.050
 8  1.150
 9  1.250
10  1.350
   THRUST COEF ARRAY     (10X 6) =
 1 0.5081
 2 0.4735
 3 0.4355
 4 0.3948
 5 0.3517
 6 0.3065
 7 0.2597
 8 0.2117
 9 0.1628
10 0.1136
   TORQUE COEF ARRAY     (10X 6) =
 1 0.1086
 2 0.1022
 3 0.9526E-01
 4 0.8774E-01
 5 0.7968E-01
 6 0.7111E-01
 7 0.6203E-01
 8 0.5247E-01
 9 0.4244E-01
10 0.3196E-01
   PITCH RATIO ARRAY     ( 1X 6) =
 1  1.465
ELECTRIC PLANT
   GEN SIZE IND           = GIVEN
   GEN KW                 =  1500.00
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    GEN NO IND              = GIVEN
    NO SS GEN               =  4.00000
    SS ENG TYPE IND         = GT
    AVG 24 HR ELECT LOAD =  2669.38
    TOTAL ELECT LOAD        =  4091.73
    ELECT MARGIN FAC        = 0.440000
    FREQ CONV IND           = NEW
COMMAND+SURVEILLANCE
  SONAR SYSTEM
    SONAR DOME IND          = PRESENT
    SONAR NAME TBL         ( 1X 4) =
 1 CONFORMAL AND TRANSMIT PLANAR ARRAYS
    SONAR WT ARRAY         ( 4X 1) = LTON
 1 0.0000E+00
 2  210.0
 3  200.0
 4 0.0000E+00
    SONAR KG ARRAY         ( 4X 1) = FT
 1 0.0000E+00
 2  5.000
 3  5.000
 4 0.0000E+00
    SONAR AREA ARRAY       ( 1X 2) = FT2
 1  495.0     0.0000E+00
    SONAR KW                =  400.000
    SONAR DISP              = 0.000000E+00 LTON
    SONAR CB ARRAY         ( 2X 1) = FT
 1  85.00
 2  5.000
    SONAR SECT AREA         = 0.000000E+00 FT2
    SONAR DRAG FAC ARRAY(31X 1) =
 1 0.0000E+00
 2 0.0000E+00
 3 0.0000E+00
 4 0.0000E+00
 5 0.0000E+00
 6 0.0000E+00
 7 0.0000E+00
 8 0.0000E+00
 9 0.0000E+00
10 0.0000E+00
11 0.0000E+00
12 0.0000E+00
13 0.0000E+00
14 0.0000E+00
15 0.0000E+00
16 0.0000E+00
17 0.0000E+00
18 0.0000E+00
19 0.0000E+00
20 0.0000E+00
21 0.0000E+00
22 0.0000E+00
23 0.0000E+00
24 0.0000E+00
25 0.0000E+00
26 0.0000E+00
27 0.0000E+00
28 0.0000E+00
29 0.0000E+00
```

```
30 0.0000E+00
31 0.0000E+00
AUXILIARY SYSTEMS
    VENT SYS IND           = STD
    FAN COIL IND           = PRESENT
    COLL PROTECT SYS IND = PARTIAL
    NO AUX BOILERS         = 0.000000E+00
    FIREMAIN SYS IND       = NEW
    PRAIRIE MASK SYS IND = PRESENT
    RUDDER SIZE IND        = CALC
    RUDDER AREA            =  223.088      FT2
    ROLL FIN AREA          =  70.0000      FT2
    NO FIN PAIRS           =  1.00000
    UNREP GEAR IND         = STREAM
    NO ANCHORS             =  2.00000
    POLLUTION CNTL IND     = PRESENT
OUTFIT+FURNISHINGS
    UNIT COMMANDER IND     = NONE
    CREW ACCOM ARRAY      ( 3X 1) =
 1  29.00
 2  21.00
 3  251.0
    HAB STANDARD FAC       = 0.000000E+00
    HAB OUTFIT IND         = MODERN
    STOWAGE TYPE IND       = VIDMAR
WEIGHT MARGINS
    GROWTH WT MARGIN       = 0.000000E+00 LTON
    D+B WT MARGIN IND      = FRACTION
    D+B WT MARGIN          =  473.346      LTON
    D+B WT MARGIN FAC      = 0.125000
    D+B KG MARGIN IND      = FRACTION
    D+B KG MARGIN          =  2.74062      FT
    D+B KG MARGIN FAC      = 0.125000
FULL LOADS
  STORES
    STORES PERIOD ARRAY ( 4X 1) =
 1  45.00
 2  30.00
 3  45.00
 4  45.00
  FUELS+LUBRICANTS
    USABLE FUEL WT         =  865.024      LTON
    FUEL LCG               = 0.503015
    BALLAST FUEL FRAC      = 0.100000E-02
RESISTANCE FACTORS
    FRICTION LINE IND      = ITTC
    DRAG MARGIN FAC        = 0.800000E-01
    WORM CURVE ARRAY      (31X 1) =
 1 0.9300
 2 0.9300
 3 0.9300
 4  1.025
 5  1.145
 6  1.137
 7  1.043
 8  1.020
 9  1.035
10  1.050
11  1.075
12  1.060
```

```
13  1.030
14  1.015
15  1.008
16  1.004
17 0.9700
18 0.9200
19 0.9000
20 0.8880
21 0.8880
22 0.8880
23 0.8880
24 0.8880
25 0.8880
26 0.8880
27 0.8880
28 0.8880
29 0.8880
30 0.8880
31 0.8880
    CORRELATION ALLOW     = 0.500000E-03
    DESIGN DRAG           =  332199.      LBF
    ENDURANCE DRAG        =  101359.      LBF
    DESIGN EHP EXPON      =  5.24448
    ENDURANCE EHP EXPON   =  4.55822
WEIGHT FACTORS
  SHIP WEIGHT
    SHIP LCG INPUT IND    = CALC
    FULL LOAD WT     .    =  5537.29      LTON
    FULL LOAD CG ARRAY   ( 2X 1) =
 1 0.5059
 2 0.5735
    SHIP WT ARRAY        ( 8X 1) = LTON
 1  1301.
 2  429.6
 3  248.4
 4  649.6
 5  634.6
 6  394.0
 7  130.0
 8  473.3
  WEIGHT ADJUSTMENTS
    WT ADJ ARRAY         ( 8X 1) = LTON
 1 -10.00
 2 0.0000E+00
 3 0.0000E+00
 4 0.0000E+00
 5 0.0000E+00
 6 0.0000E+00
 7 0.0000E+00
 8 0.0000E+00
    WT ADJ CG ARRAY      ( 8X 2) =
 1 0.5500     0.9000
 2 0.0000E+00 0.0000E+00
 3 0.0000E+00 0.0000E+00
 4 0.0000E+00 0.0000E+00
 5 0.0000E+00 0.0000E+00
 6 0.0000E+00 0.0000E+00
 7 0.0000E+00 0.0000E+00
 8 0.0000E+00 0.0000E+00
PERFORMANCE FACTORS
```

```
     SIG WAVE HT            = 0.100000E+37 FT
     MONTHS IN SERVICE      = 0.100000E+37
     SIG WAVE HT ARRAY    ( 5X 1) = FT
  1 0.1000E+37
     SEA STATE PROB ARRAY( 5X 1) =
  1 0.1000E+37
     MSN SPEED ARRAY      ( 5X 1) =
  1 0.1000E+37
     MSN SPEED PROB ARRAY( 5X 1) =
  1 0.1000E+37
     HULL FOULING FAC       = 0.100000E+37
     PROP FOULING FAC       = 0.100000E+37
     AVAIL FUEL FRAC        = 0.100000E+37
 HYDROSTATIC FACTORS
   HYDROSTATIC BASELINE
     APPENDAGE IND          = WITH
     HYDROSTATIC IND        = FULL LOAD
     HYDROSTATIC DRAFT      = 0.100000E+37 FT
     HYDROSTATIC TRIM       = 0.100000E+37 FT
     HYDROSTATIC WT         = 0.100000E+37 LTON
     HYDROSTATIC LCG        = 0.100000E+37 FT
     HYDROSTATIC KG         = 0.100000E+37 FT
   FLOODABLE LENGTH
     FL LGTH PERM ARRAY   ( 4X 1) =
  1 0.1000E+37
   INTACT STABILITY
     INTACT WIND SPEED      =  100.000
     TURN RADIUS            = 0.100000E+37 FT
     TURN SPEED             = 0.100000E+37
   DAMAGED STABILITY
     COMP PERM ARRAY      (17X 1) =
  1 0.1000E+37
     COMP SYM INDEX ARRAY(17X 1) =
  1 0.1000E+37
     DAMAGED COMP ARRAY   (17X 1) =
  1 0.1000E+37
 SPACE FACTORS
     VOL ADJ ARRAY        ( 4X 1) =
  1 0.0000E+00
  2 0.0000E+00
  3 0.0000E+00
  4 0.0000E+00
     SPACE MARGIN FAC       = 0.000000E+00
     PASSWAY MARGIN FAC     = 0.000000E+00
     DKHS AVG DECK HT       =  8.50000      FT
     REFER MACHY LOC IND    = INSIDE
 COST FACTORS
   ECONOMIC FACTORS
     YEAR $                 =  1985.00
     INFLATION RATE ARRAY(15X 1) =
  1 0.1000E+37
     PRODUCTION RATE        =  5.00000
     LEARNING RATE          = 0.970000
     FUEL COST              =  1.20000      $/GAL
   PAYLOAD COST FACTORS
     PAYLOAD T+E COST       =  43.6000
     LEAD PAYLOAD COST      =  307.900
     FOLLOW PAYLOAD COST    =  276.200
     ANNUAL TRNG ORD COST   = 0.100000E+37
     PAYLOAD FUEL RATE      = 0.100000E+37 LTON/HR
```

```
 SHIP COST FACTORS
    IOC DATE                = 2005.00
    R+D PROGRAM LENGTH      =  5.00000
    NO OF SHIPS ACQUIRED =  30.0000
    PROFIT FRAC             = 0.800000E-01
    SERVICE LIFE            =  30.0000
    ANNUAL OPERATING HRS = 0.100000E+37
    TECH ADV COST           = 0.000000E+00
    ADDL FACILITY COST      = 0.000000E+00
    DEFERRED MMHRS REQ      = 0.000000E+00
    UNREP UNIT CAPACITY     = 0.100000E+37 LTON/YR
    UNREP UNIT COST         = 0.100000E+37
    UNREP O+S COST          = 0.100000E+37
    KN FACTOR ARRAY        ( 9X 1) =
 1 0.9830
 2  2.345
 3  1.000
 4  3.153
 5  1.528
 6  1.000
 7  1.000
 8  26.06
 9  4.254
    SHIP FUEL RATE          = 0.100000E+37 LTON/HR
MANNING FACTORS
    MANNING FACTOR ARRAY( 6X 1) =
 1 0.1000E+37
    WRKLOAD FACTOR ARRAY( 6X 1) =
 1 0.1000E+37
    AVIATION DEPT ARRAY ( 3X 1) =
 1  9.000
 2  3.000
 3  30.00
    NO WATCH STANDERS       = 0.100000E+37

C,E>EXIT
```

DESIGN CALCULATIONS

1. ASSET Weight Adjustment

SSES Module weight specifications include main deck scantlings. Therefore, a weight adjustment was made to the ASSET Group 100 estimate. The weight (W) is given by:

$$W = \gamma A t_{m}/12$$

where:

γ = Hull material density

A = Deck Area

t_{m} = Main Deck smeared thicknesss

2. ASSET Cost Analysis Data

a. Payload Cost - Cost equations given in the ASSET theory manual were used to calculate the lead, follow, and T&E payload costs using a value of 675 tons for payload weight. The payload weight used by ASSET includes the weight of sonar water and JP-5. This practice results in an unrealistically high payload cost for the ASW Frigate.

b. Group 100 K_N value

The default Group 100 K_N value of 1.0 is based on data for MS/HTS hulls and aluminum superstructures. A typical aluminum deckhouse represents 3.5% of the Group 100 weight. Assuming aluminum is about twice as expensive as steel to purchase and fabricate, the K_N factor for a HTS hull and deckhouse can be approximated by:

$$K_N = .965 + .035/2 = .983$$

3. Walden Extension to Bales' Rank Factor

$$\hat{R} = \hat{R}_{BALES} + 12.9x(\quad - 4300)/4300)$$

$$= 9.31 + 12.9(5537-4300)/4300 = 13.02$$

4. Minimum Freeboard Calculation (DDS 079-2)

$$100FBD_o/LBP = 1.01x(100T/LBP) - .000636(LBP) + 2.78$$

$$= 1.10(4.42) - .000636(425) + 2.78 = 6.97$$

$$\therefore FBD_o \geq 6.97(425)/100 = 29.6 \text{ FT}$$

APPENDIX B

TECHNOLOGY CHARACTERIZATION SHEETS

HSLA CHARACTERIZATION SHEET

Name of Technology: High Strength Low Alloy Steel

References:

[1] Rains, Dean A., "HM&E Technology Characterization and Evaluation for a Frigate," Decision Engineering, Pascagoula, Ms, 30 APR 84.

[2] Russell, John F., "DDG-51 Producibility Studies Task 7," Quincy Shipbuilding Division, General Dynamics, Quincy, Ma, 17 JAN 83.

Brief Description:

HSLA has the desirable properties of high strength with low fabrication and material costs, making it competitive in most shipboard applications. It is being considered for two types of application on future combatant ships: Replace HY-80 for current high strength/balistic protection needs, and second replace HTS steel in many routine needs.

HSLA has material properties comparable with HY-80, yet costs significantly less and is easier to weld. HSLA steels obtain their material properties in part by careful selection of their alloying elements and by using either fine graining techniques, precipitation hardening, or a combination of both.

Categorization: Circle appropriate items.

1. Direct Influence on Ship Performance

   a. Combat Capability (specify warfare area)

   b. Survivability (signature, protection)

   c. Mobility (sustained speed, range, maneuveribility)

   d. Seakeeping

   e. Operability (reliability, maintainability, availability, ease of operation)

HSLA CHARACTERIZATION (CONTINUED)

2. Functional Area Affected by Technology

   a. Combat System

   b. Containment

   c. Main Propulsion

   d. Electrical

   e. Auxiliary

   f. Outfit/Human Support

3. Ship Impact

   a. Weight: Hull, Superstructure, Topside

   b. Space: Location - Hull, Superstructure
   Type - Deck Area, Large Object, Tankage

   c. Energy

   d. Manning

4. Applicable Ship Size/Type

   a. Size: CV CG DD FF PF

   b. Type: Monohull SWATH SES HYDROFOIL ACV

5. Cost

   a. Will the technology provide a direct reduction in cost ? y / n

      Reduction in material and fabrication cost compared to HY-80.

   b. Type of Cost: Acquisition, Operating and Support

<u>Development Status:</u>

Certification program underway:

1. Strength and ballistic properties certified.

2. Crack arresting properties being tested.

HSLA CHARACTERIZATION (CONTINUED)

Technical Information:

MATERIAL PROPERTIES

	HTS	HSLA/HY-80
MTRL DENSITY [LBM/FT3]	489.0	489.0
MOD OF ELAS [KSI]	29600	29600
YIELD STRENGTH [KSI]	45.00	80.00
PROPORTNL LIMIT [KSI]	34.00	60.00
MAX PRIMARY STRESS [KSI]	21.28	23.52
ALW WORK STRESS [KSI]	38.00	55.00
POISSONS RATIO	0.30	0.30

STRESS COEFFICIENT (C) VALUES FOR PLATE PANEL DESIGN

	HTS	HSLA/HY-80
TOPSIDE	400	500
LOWER SHELL/TANK	630	750
FLOODING/DAMAGE CONTROL	800	900

DECKHOUSE STRUCTURAL DENSITY [LBM/FT3]

HTS	4.18
HSLA/HY-80	3.22

Unburdened cost for HSLA approximately 1.4 times HTS compared to 1.8 for HY-80.

IMPACT EVALUATION OF HSLA USING ASSET

1. HSLA Hull

ASSET currently does not handle hybrid hull structures (i.e., crack arrestors, high strength deck plating, etc.). Only one set of material properties, stress characteristics, and plate stress coefficients may be specified. In order to evaluate the effect of using HSLA for the design of the primary hull structure, the following changes were made to the baseline MFL.

a. Hull Materials

```
HULL MTRL TYPE IND      = OTHER
HULL YIELD STRENGTH     = 80.00
HULL PROPORTNL LIMIT    = 60.00
HULL MAX PRIM STRESS    = 23.52
HULL ALW WORK STRESS    = 55.00
C COEF ARRAY
                   1   500.0
                   2   750.0
                   3   900.0
```

b. Cost Factors

The Group 100 K_N factor was determined using the value for of 0.983 (HTS Hull and Superstructure) as a baseline value. The percentage of Group 100 weight proportioned to the superstructure was determined . The K_N value was then estimated based on the data that HSLA increases hull construction costs by 1.4.

$$W_{150}/W_{100} = 155.9/1251.3 = .125$$

$$K_N = 1.4(.875)(.983) + (.125)(.983) = 1.327$$

2. <u>HSLA Deckhouse</u>

No attempt has been made in ASSET Structure Module to define the structural load or size requirements for the deckhouse. An empirical weight approach, combined with the deckhouse geometry, is used to determine each deckhouse weight. The weight has been characterized as a function of enclosed deckhouse volume. In order to evaluate the effect of constructing the deckhouse out of HSLA, the following changes were made to the baseline MPL.

a. Deckhouse Materials

DKHS MTRL TYPE IND = OTHER
DKHS STRUCT DENSITY = 3.220

b. Cost Factors

$K_N = (.905)(.983) + 1.4(.095)(.983)$

NAVTRUSS CHARACTERIZATION SHEET

Name of Technology: NAVTRUSS

References:

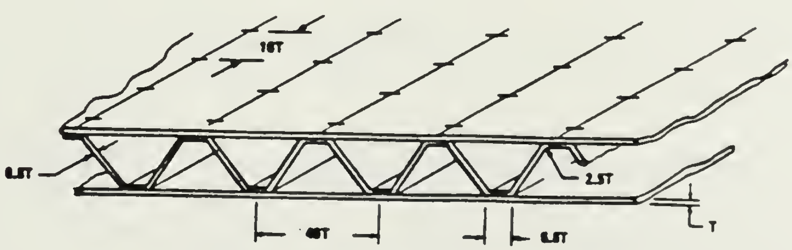
[1] Rains, Dean A.,"HM&E Technology Characterization and Evaluation for a Frigate," Decision Engineering, Pascagoula, Ms, 30 APR 84.

[2] Russell,John F., "DDG-51 Producibility Studies Task 7," Quincy Shipbuilding Division, General Dynamics, Quincy, Ma, 17 JAN 83.

Brief Description:

NAVTRUSS is a trade name for steel sandwich type panel structure with a corrugated core. A typical section is shown below. This type of configuration employs very thin face sheet and is on the order of 75 percent ligther than corresponding stiffened plate structure. NAVTRUSS may be practical for superstructure sides because of its' lightweight, but is not considered to be practical for deck structure due to the nonuniform nature of deck loading. If fragmentation protection is desired then KEVLAR or local reinforcement is required.

NAVTRUSS



NAVTRUSS CHARACTERIZATION (CONTINUED)

Categorization: Circle appropriate items.

1. Direct Influence on Ship Performance

    a. Combat Capability (specify warfare area)

    b. Survivability (signature, protection)

        Combined with KEVLAR it could increase ballistic protection for given weight allocation.

    c. Mobility (sustained speed, range, maneuveribility)

    d. Seakeeping

    e. Operability (reliability, maintainability, availability, ease of operation)

        Maintenance requirements of NAVTRUS are being investigated.

2. Functional Area Affected by Technology

    a. Combat System

    b. Containment

    c. Main Propulsion

    d. Electrical

    e. Auxiliary

    f. Outfit/Human Support

3. Ship Impact

    a. Weight: Hull, Superstructure, Topside

    b. Space: Location - Hull, Superstructure
    Type - Deck Area, Large Object, Tankage

    c. Energy

    d. Manning

NAVTRUSS CHARACTERIZATION (CONTINUED)

4. Applicable Ship Size/Type

   a. Size: CV CG DD FF PF

   b. Type: Monohull SWATH SES HYDROFOIL ACV

5. Cost

   a. Will the technology provide a direct reduction in cost ? y / n

      Will increase material and fabrication cost.

   b. Type of Cost: Acquisition, Operating and Support

Development Status:

NAVTRUSS CIWS deckhouse installed on a DD-963 class ship. Candidate materials undergoing corrosion testing. Structural and ballistic characteristics of panels have been tested.

Technical Information:

DECKHOUSE STRUCTURAL DENSITY [LBM/FT3]

HTS	4.18
NAVTRUSS	2.39

Unburdened cost for NAVTRUSS is approximately 6 times HTS.

IRGT CHARACTERIZATION SHEET

Name of Technology: Intercooled/Regenerative Gas Turbine

References:

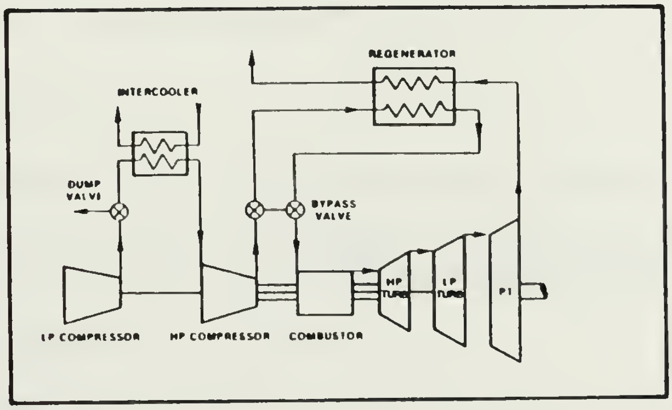
[1] Rains, Dean A., "HM&E Technology Characterization and Evaluation for a Frigate," Decision Engineering, Pascagoula, Ms, 30 APR 84.

[2] Baskerville, J.E., E.R. Quandt & M.R. Donovan, "Future Propulsion Machinery Technology for Gas Turbine Powered Frigates, Destroyers, and Cruisers," Naval Engineers Journal, MAR 78, pp. 34-46.

[3] Bowen, T.L. & D.A. Groghan, "Advanced-Cycle Gas Turbines for Naval Ship Propulsion," Naval Engineers Journal, MAY 84, pp. 262-271.

Brief Description:

Regenerative heating of the gas entering the combustor using the gas leaving the power turbine, and cooling of the LP delivery air to the HP compressor offer the potential of improved fuel consumption rates without the complexity of a supplemental steam cycle (COGAS). Assuming successful developments, the above adaptations to the simple cycle could provide specific fuel consumption rates approaching .30 LBM/HP-HR. In addition, these cycle changes are projected to yield a flat SFC characteristic far down the power curve from the design point, as desired for a ship mission profile.



IRGT CHARACTERIZATION (CONTINUED)

Categorization: Circle appropriate items.

1. Direct Influence on Ship Performance

   a. Combat Capability (specify warfare area)

   b. Survivability (signature protection)

      Some reduction in IR signature without external cooling techniques.

   c. Mobility (sustained speed, range, maneuveribility)

   d. Seakeeping

   e. Operability (reliability, maintainability, availability, ease of operation)

      Additional equipment/complexity added to the machinery plant.

2. Functional Area Affected by Technology

   a. Combat System

   b. Containment

   c. Main Propulsion

   d. Electrical

   e. Auxiliary

   f. Outfit/Human Support

3. Ship Impact

   a. Weight: Hull, Superstructure, Topside

   b. Space: Location - Hull, Superstructure
      Type - Deck Area, Large Object, Tankage

   c. Energy

   d. Manning

IRGT CHARACTERIZATION (CONTINUED)

4. Applicable Ship Size/Type

   a. Size: CV CG DD FF PF

   b. Type: Monohull SWATH SES HYDROFOIL ACV

5. Cost

   a. Will the technology provide a direct reduction in cost ? y/n

      Will increase cost of main engines, but will decrease O&S costs because of fuel conservation.

   b. Type of Cost: Acquisition, Operating and Support

Development Status:

Exploratory research has been conducted at DTNSRDC to determine technical feasibility. Contractor studies were conducted in 1983 with each of the major aircraft engine manufacturers.

Technical Information:

General Electric data for constant speed, variable power Intercooled/Regenerative Gas Turbine.

	LM-2500	IRGT
MAX CONT PWR [HP]	26,250	26,250
CONT RPM	3600	3600
SPEC WT [LBM/HP]	1.99	3.70
VOLUME REQMT	BLV	BLV+1000 FT3

BLV = Baseline Value

COMPARATIVE SFC [LBM/HP-HR] DATA

BHP	LM-2500	IRGT
5000	.680	.380
10000	.540	.340
15000	.450	.335
20000	.430	.330
25000	.410	.330

Unburdened cost for each main engine approximately 1.2 times LM-2500.

IMPACT EVALUATION OF IRGT MAIN ENGINES USING ASSET

1. Discussion

ASSET assumes a standard LM-2500 SFC curve for gas turbine main engines. The program currently does not provide the ability to adjust the shape of the curve. Hence, in order to model a IRGT properly at endurance for fuel weight calculations, a false SFC at maximum power must be entered. This false value is determined by guessing a value, balancing the design, and then running the Machinery Module to check that the SFC is correct at endurance. Note that the SFC value given in the Machinery Module includes two factors: one for plant deterioration (1.05) and another for instrument inaccuracy (depends on % maximum power). The proper modeling of IRGT main engines for the ASW Frigate required the following changes to the baseline MPL.

2. Adjustments

a. Main Engine

MAIN ENG SFC = 0.28
MAIN ENG SPEC WT = 3.70

The value of 0.28 for SFC at maximum power resulted in the correct value of 0.37 at endurance where 9811 HP was required to make 20 KT.

b. Cost Factors

The cost of two LM-2500 is approximately $10M. Since IRGT engines are 20% more expensive, the Group 200 K_N was adjusted until the Group 200 cost increased by $2.0M. This resulted in a K_N value of 2.454.

c. Volume Adjustment

An adjustment to 2000 FT^3 was added to mobility volume.

CONTRARDTATING PROPELLER CHARACTERIZATION SHEET

Name of Technology: Contrarotating Propeller

References:

[1] Rains, Dean A., "HM&E Technology Characterization and Evaluation for a Frigate," Decision Engineering, Pascagoula, Ms, 30 APR 84.

[2] Tsao, S.K., ASSET Propeller Module Theory Manual, Boeing Computer Services Company, Seattle, Wa, JUN 83

Brief Description:

Contrarotating propellers consist of two propellers on concentric shafts (one inside the other) rotating in opposite directions. Power is normally provided via eplicyclic reduction gearing or direct drive electric motors. Contrarotating propellers offer improved propulsion efficiency. Acoustics need to be further investigated.

Categorization: Circle appropriate items.

1. Direct Influence on Ship Performance

   a. Combat Capability (specify warfare area)

   b. Survivability (signature protection)

   c. Mobility (sustained speed, range, maneuveribility)

   d. Seakeeping

   e. Operability (reliability, maintainability, availability, ease of operation)

   More complex propulsor and drive train.

CONTRAROTATING PROPELLER CHARACTERIZATION (CONTINUED)

2. Functional Area Affected by Technology

   a. Combat System

   b. Containment

   c. Main Propulsion

   d. Electrical

   e. Auxiliary

   f. Outfit/Human Support

3. Ship Impact

   a. Weight: Hull, Superstructure, Topside

   b. Space: Location - Hull, Superstructure
      Type - Deck Area, Large Object, Tankage

   c. Energy

   d. Manning

4. Applicable Ship Size/Type

   a. Size: CV CG DD FF PF

   b. Type: Monohull SWATH SES HYDROFOIL ACV

5. Cost

   a. Will the technology provide a direct reduction in cost ? y / n

      Will increase acquisition cost.

   b. Type of Cost: Acquisition, Operating and Support

Development Status:

An early system was tested at sea on a SSN. Numerous model tests have been conducted.

CONTRAROTATING PROPELLER CHARACTERIZATION (CONTINUED)

Technical Information:

TYPICAL PROPELLER PERFORMNACE DATA

SPEED [KT]	PROPULSIVE COEFFICIENT CRP	FP	CR
20	.70	.73	.80
30	.69	.71	.78

Drag estimates for shafts and struts expressed as a fraction of the total bare hull resistance for different configurations are as follows:

	NO. PROP SHAFTS 1	2
Fixed Pitch	.03	.05
Controllable/Reversable Pitch (CRP)	.08	.12
Contrarotating	.08	.08

Propeller system (propellers, struts and shafting) weight is expected to be comparable to a CRP system.

An increase in unburdened Group 200 cost of approximately $2 M per shaft is anticipated over a simple FP system.

IMPACT EVALUATION OF CR PROPELLER USING ASSET

1. Discussion

ASSET directly handles contrarotating propellers. Since powering data was unknown (need to run self-propelled model tests), the relative rotative efficiency was adjusted until a propulsive coefficient of .80 was obtained.

2. Adjustments

a. Powering

REL ROTATE EFF = 1.114

b. Propeller

PROP TYPE IND = CR
NO BLADES = 9

c. Cost Factors

The Group 200 K_N factor was adjusted until the Group 200 cost increased by $4.0M. This resulted in a K_N value of 2.575.

INTEGRATED ELECTRIC DRIVE CHARACTERIZATION SHEET

Name of Technology: Integrated Electric Drive

References:

[1] Rains, Dean A., "HM&E Technology Characterization and Evaluation for a Frigate," Decision Engineering, Pascagoula, Ms, 30 APR 84.

[2] Jolliff, J.V. & D.L. Greene, "Advanced Integrated Electric Propulsion A Reality of the Eighties," Naval Engineers Journal, APR 82, pp. 232-252.

[3] Robey, H.N. & K.T. Page, "Application of Variable Speed Constant Frequency Generators to Propulsion Derived Ship Service," Naval Engineers Journal, MAY 85, pp. 296-305.

Brief Description:

Integrated electric drive consists of prime movers driving an integrated generator arrangement. In the configuration being considered, LM-2500 gas turbines deliver power to a propulsion generator and a ship service generator via a common reduction gear. Variable speed constant frequency (VSCF) generators in combination with a dedicated ship service gas turbine generator are used to provide ship service power. Constant frequency output with variable speed input is obtained through the use of power electronics. The enclosed figure illustrates the proposed plant configuration.

This concept of integrated electric drive offers a number of advantages in addition to those inherent with a conventional electric drive plant.

1. Overall plant operation is more efficient (fuel economy close to diesel plants).

2. Reduced number of installed prime movers.

3. Reduction in volume required for ship support.

INTEGRATED ELECTRIC DRIVE CHARACTERIZATION (CONTINUED)

Categorization: Circle appropriate items.

1. Direct Influence on Ship Performance

   a. Combat Capability (specify warfare area)

   b. Survivability (signature, protection)

      Arrangement flexibility inherent in electric drive systems.

   c. Mobility (sustained speed, range, maneuveribility)

      Reduction in V_s due to less power available for propulsion, increase in range for same fuel weight

   d. Seakeeping

   e. Operability (reliability, maintainability, availability, ease of operation)

      Complexed power electronics and reduction gearing associated with propulsion derived ship service.

2. Functional Area Affected by Technology

   a. Combat System

   b. Containment

   c. Main Propulsion

   d. Electrical

   e. Auxiliary

   f. Outfit/Human Support

3. Ship Impact

   a. Weight: Hull, Superstructure, Topside

   b. Space Location - Hull, Superstructure
      Type - Deck Area, Large Object, Tankage

   c. Energy

   d. Manning

INTEGRATED ELECTRIC DRIVE CHARACTERIZATION (CONTINUED)

4. Applicable Ship Size/Type

   a. Size: CV CG DD FF PF

   b. Type: Monohull SWATH SES HYDROFOIL ACV

5. Cost

   a. Will the technology provide a direct reduction in cost? y / n

      Will increase cost of propulsion plant, but should lower O&S costs because of fuel economy.

   b. Type of Cost: Acquisition, Operating and Support

Development Status:

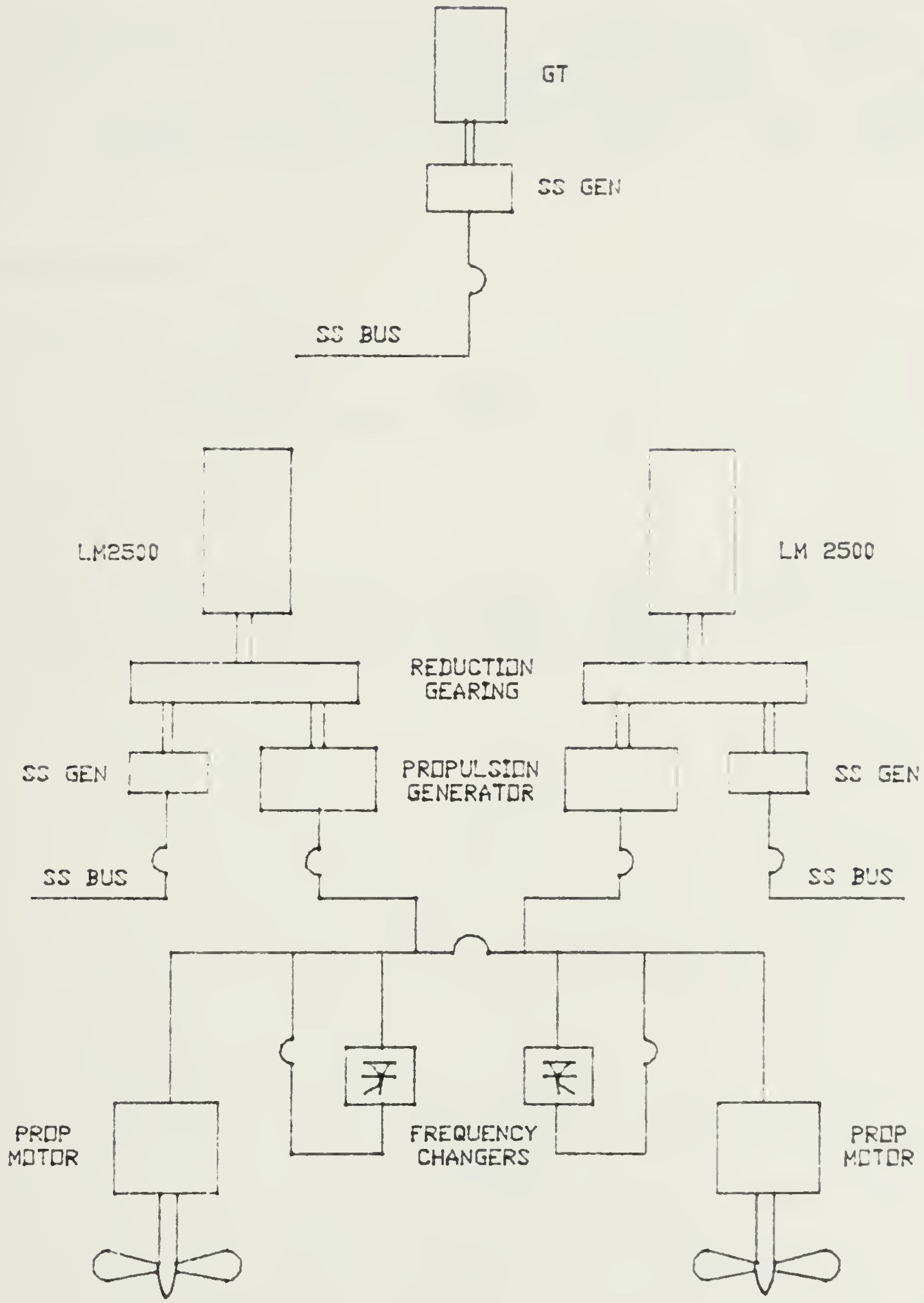
Exploratory research has been conducted at DTNSRDC to determine technical feasibility.

Technical Information:

Propulsion derived ship service, compared to dedicated units, offers weight savings approximately equivalent to the two prime movers removed and volume savings roughly equivalent to an auxiliary machinery space (25,000 FT^3).

The combined unburdened cost of Group 200 and 300 is anticipated to be about the same as a conventional electric drive system. The higher cost of the VSCF generators is offset by the removal of seperate prime movers for each generator.

INTEGRATED ELECTRIC DRIVE SCHEMATIC



IMPACT EVALUATION OF INTEGRATED ELECTRIC DRIVE USING ASSET

1. Discussion

ASSET directly handles integrated electric drive. However, ASSET does not allow flexibility in the number of generators. The program assumes the number of generators is equal to the number of main engines plus one. In addition, ASSET assumes direct drive motors and water cooled technology.

2. Adjustments

a. Electric Plant

GEN NO IND = CALC
SS ENG TYPE IND = PROPULSION

b. Cost factors

The Group 200 K_N factor was adjusted until the sum of the Group 200 and 300 costs for the variant was the same as the sum for the baseline.

ROTARY ENGINE SSG CHARACTERIZATION SHEET

Name of Technology: Rotary Engine Ship Service Generator

Reference:

[1] Rains, Dean A., "HM&E Technology Characterization and Evaluation for a Frigate," Decision Engineering, Pascagoula, Ms, 30 APR 84.

Brief Description:

Rotary engine ship service generators offer the SFC rates of diesels at system weights comparable to gas turbines. They represent an extension of the same technology used successfully in the automobile industry. Conventional gas turbine and diesel generator sets are compared on an equal basis in the technical section.

Categorization: Circle appropriate items.

1. Direct Influence on Ship Performance

   a. Combat Capability (specify warfare area)

   b. Survivability (signature, protection)

      Radiated noise levels for the rotary engine are expected to be less than a diesel but not as favorable as a gas turbine.

   c. Mobility (sustained speed, range, maneuveribility)

   d. Seakeeping

   e. Operability (reliability, maintainability, availability, ease of operation)

      RM&A requires investigation.

ROTARY ENGINE SSG CHARACTERIZATIION (CONTINUED)

2. Functional Area Affected by Technology

   a. Combat System

   b. Containment

   c. Main Propulsion

   d. Electrical

   e. Auxiliary

   f. Outfit/Human Support

3. Ship Impact

   a. Weight: Hull, Superstructure, Topside

   b. Space: Location - Hull, Superstructure
   Type - Deck Area, Large Object, Tankage

   c. Energy

   d. Manning

4. Applicable Ship Size/Type

   a. Size: CV CG DD FF PF

   b. Type: Monohull SWATH SES HYDROFOIL ACV

5. Cost

   a. Will the technology provide a direct reduction in cost ? y / n

   Less expensive per KW than diesel or gas turbine.
   Fuel economy comparable to diesel.

   b. Type of Cost: Acquisition, Operating and Support

ROTARY ENGINE SSG CHARACTERIZATION (CONTINUED)

Development Status:

Exploratory research has been conducted at DTNSRDC to determine technical feasibility.

Technical Information:

	Rating [KW]	Spec Vol [FT3/KW]	Spec Wt [LT/KW]	SFC @ MAX [LB/HP-HR]	COST [$/KW]
Diesel	2000	4.68	.0367	.400	350
Gas Turbine	2000	2.34	.0197	.569	400
Rotary	2150	2.25	.0178	.424	265

IMPACT EVALUATION OF ROTARY ENGINE SSG USING ASSET

1. Discussion

ASSET does not offer rotary engines as an option for the electric plant. However, they may be indirectly handled by selecting diesels as the ship service engine and then making adjustments to weight and volume estimates. This is reasonable since diesel and rotary engines have equivalent SFC characteristics.

2. Adjustments

a. Electric Plant

SS ENG TYPE IND = DIESEL

b. Weight Adjustments

The lower specific weight of the rotary engine required a reduction of 50 tons in Group 300 weight. In addition, Group 600 weight was reduced 20 tons to reflect a decrease in the amount of insulation requried by the rotary engine. Note that this resulted in 20 tons of insulation for the rotary engine compared to none for the gas turbine and 40 tons for the diesel.

c. Volume Adjustment

A decrease of 5000 FT^3 was made in the ship support volume.

d. Cost Factors

Generation represents about one third of the Group 300 weight. Hence, the 25% reduction in cost for the rotary engine was applied to 33% of the baseline Group 300 K_N value of 1.0.

$$K_N = (.67)(1.0) + .75(.33)(1.0) = 0.917$$

COMPOSITE MAST AND LADDER CHARACTERIZATION SHEET

Name of Technology: Composite Masts and Topside Ladders

References:

[1] Rains, Dean A., "HM&E Technology Characterization and Evaluation for a Frigate," Decision Engineering, Pascagoula, Ms, 30 APR 84.

Brief Description:

The principal advantage of the use of reinforced plastics is reduced weight. Composites also offer corrosion resistance and favorable EMI characteristics. However, there are few cost advantages, especially if exotic carbon or boron fibers are required for stiffness or strength. Additionally, there is concern over the ability of the materials to resist and survive fires.

Categorization: Circle appropriate items.

1. Direct Influence on Ship Performance

   a. Combat Capability (specify warfare area)

      EMI may be improved.

   b. Survivability (signature, protection)

   c. Mobility (sustained speed, range, maneuveribility)

   d. Seakeeping

   e. Operability (reliability, maintainability, availability, ease of operation)

2. Functional Area Affected by Technology

   a. Combat System

   b. Containment

   c. Main Propulsion

   d. Electrical

   e. Auxiliary

   f. Outfit/Human Support

COMPOSITE MAST AND TOPSIDE LADDER CHARACTERIZATION (CONT.)

3. Ship Impact

   a. Weight: Hull, Superstructure, Topside

   b. Space: Location - Hull, Superstructure
      Type - Deck Area, Large Object, Tankage

   c. Energy

   d. Manning

4. Applicable Ship Size/Type

   a. Size: CV CG DD FF PF

   b. Type: Monohull SWATH SES HYDROFOIL ACV

5. Cost

   a. Will the technology provide a direct reduction in cost ? y / n

   b. Type of Cost: Acquisition, Operating and Support

Development Status:

Technical Information:

The following are typical weight savings based on DD-963 studies conducted by INGALLS Shipbuilding. Rough rule of thumb is 60% weight saving.

	Wt Savings [LT]
Masts	4.8
Topside Ladders	1.2

Cost is approximately 2 times HTS.

IMPACT EVALUATION OF COMPOSITE MASTS & LADDERS USING ASSET

1. Discussion

Analysis must be conducted to determine the possible weight savings. Ship impact may then be assessed by entering the data as weight adjustments to ASSET.

2. Adjustments

a. Weight Adjustments

Weight savings of 4.8 tons were applied to Group 100 for the mast structure and 1.2 tons were applied to Group 600 for the ladders.

b. Cost factors

The K_N factor adjustments were done according to weight fractions. The masts represent 0.4% of Group 100. The ladders represent 0.9% of Group 600 weight.

Group 100 $K_N = (.996)(.983) + 2(.004)(.983) = 0.987$

Group 600 $K_N = (.991)(1.0) + 2(.009)(1.0) = 1.009$

APPENDIX C

TECHNOLOGY IMPACT ANALYSIS RESULTS

COMPARISON OF MAJOR CHARACTERISTICS
BASELINE ASW FRIGATE VERSUS HSLA HULL VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
<u>Ship Performance</u>				
1. Combat System				
Capacity				
Payload [LT]	675.0	675.0	675.0	
Area [FT^2]	16254	16254	16254	
Effectiveness				
Arrangeability		BLV	Same	
2. Survivability				
Signatures				
IR	DDG-51	TBD	TBD	
RCS	DDG-51	TBD	TBD	
Noise	DD-963	TBD	TBD	
Visual	DD-963	TBD	TBD	
Protection				
Blast	3 PSI	3 PSI	3 PSI	
Frag	LV II	LV II	Improved	
NBC	P-CPS	P-CPS	P-CPS	
Shock	.3 KSF	.3 KSF	.3 KSF	
3. Mobility(1)				
V_S [KT]	24.0	27.95	28.01	0.2
V_E [KT]	20.0	20.0	20.0	
Range [NM]	4500	4500	4500	
Maneuverability	FF	TBD	TBD	
4. Seakeeping				
Rank Factor		13.02	12.95	-0.5
Roll Period [SEC]		10.01	9.87	-1.4
5. Operability				
RM&A	FFG-7	TBD	TBD	

Note: (1) Sustained speed requirement for sea state 5. Baseline and Variant values given are for calm water. An estimate of the added resistance in waves could be made, but the speed loss should not be enough to drop speed below threshold.

COMPARISON OF BASELINE VS HSLA HULL VARIANT (CONT)

	THRESHOLD	BASELINE	VARIANT	DIFF %
Design Margins/Criteria				
1. Margins				
Acq Weight	12.5%	12.5	12.5	
Acq KG	12.5%	12.5	12.5	
Space	0.0%	0.0	0.0	
Acq Electrical	20.0%	20.0	20.0	
S.L. Electrical	20.0%	20.8	20.8	
Propulsion Power	8.0%	8.0	8.0	
Accomodations	10.0%	10.0	10.0	
Strength	2.24 KSI	2.78	4.53	63.0
2. Standards & Practices				
GM_T/B	.08-.12	.097	.099	2.6
FBD_o [FT]	29.6	29.7	29.9	N/S
Prim Stress [KSI]	Note (2)	18.50	18.99	2.6
Correlation Allow	.0005	.0005	.0005	
Ship Configuration				
1. Gross Characteristics				
LBP [FT]		425.0	425.0	
Beam [FT]		50.00	49.86	-0.3
Draft [FT]		18.77	18.64	-0.7
Depth [FT]		38.00	38.00	
Displacement [LT]		5537.3	5477.1	-1.1
Total Volume [FT^3]		658118	657683	N/S
GM_T [FT]		4.83	4.94	2.3
Disp Lgth Ratio		72.1	71.3	-1.1
Vol Density [LB/FT^3]		18.8	18.7	N/S
2. Powering				
SHP_I		52500	52500	
SHP_E		9859	9779	-0.8
PC_E		0.747	0.747	
SFC_E [LBM/HP-HR]		0.544	0.546	N/S
3. Ship Service				
Propulsion [KW]		267	267	
Average Load [KW]		2669	2668	N/S
Peak Load [KW]		2841	2840	N/S

Note: (2) Maximum Primary Stress Values
HTS 21.28 KSI
HSLA 23.52 KSI

COMPARISON OF BASELINE VS HSLA HULL VARIANT (CONT)

	THRESHOLD	BASELINE	VARIANT	DIFF %
4. Weight				
W_{100} [LT]		1300.7	1251.3	-3.8
W_{200}		429.6	429.5	N/S
W_{300}		248.4	248.1	N/S
W_{400}		649.6	649.4	N/S
W_{500}		634.6	634.0	N/S
W_{600}		394.0	393.9	N/S
W_{700}		130.0	130.0	
Acq Margin		473.3	467.0	-1.3
Lightship		4260.1	4203.2	-1.3
Loads		1277.2	1073.9	-0.3
Fuel		865.0	861.9	-0.4
Ship Ammo		78.5	78.5	
Aviation		172.5	172.5	
Full Load Weight		5537.3	5477.1	-1.1
Full Load KG [FT]		21.79	21.63	-0.7
Lightship KG		24.7	24.5	-0.8
5. Volume				
Hull [FT^3]		550657	550495	N/S
Deckhouse		107462	107187	N/S
V_1 Mission		148288	148266	N/S
V_2 Human Support		135750	135750	
V_3 Ship Support		196397	196287	N/S
V_4 Mobility		177384	177243	N/S
V_5 Unassigned		299	137	N/S
Total Volume		658118	657683	N/S
6. Manning				
Officer		26	26	
CPO		19	19	
Enlisted		228	228	
Accommodations		301	301	
<u>Cost</u>				
1. R&D Cost (10 yrs)		TBD	TBD	
2. Acquistion Cost				
Lead Ship [$M 1985]		970.1	987.8	1.8
Follow Ship		583.7	591.5	1.3
Average (30 Ships)		559.0	566.1	1.3
3. O&S Cost (30 yrs)		1039.9	1043.0	0.3
<u>Risk</u>				
1. Schedule		TBD	TBD	
2. Technical		LOW	MOD-LOW	
3. Cost		TBD	TBD	

COMPARISON OF MAJOR CHARACTERISTICS
BASELINE ASW FRIGATE VERSUS HSLA DECKHOUSE VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
Ship Performance				
1. Combat System				
Capacity				
Payload [LT]	675.0	675.0	675.0	
Area [FT^2]	16254	16254	16254	
Effectiveness				
Arrangeability		BLV	Same	
2. Survivability				
Signatures				
IR	DDG-51	TBD	TBD	
RCS	DDG-51	TBD	TBD	
Noise	DD-963	TBD	TBD	
Visual	DD-963	TBD	TBD	
Protection				
Blast	3 PSI	3 PSI	3 PSI	
Frag	LV II	LV II	LV II	
NBC	P-CPS	P-CPS	P-CPS	
Shock	.3 KSF	.3 KSF	.3 KSF	
3. Mobility(1)				
V_B [KT]	24.0	27.95	28.00	0.2
V_E [KT]	20.0	20.0	20.0	
Range [NM]	4500	4500	4500	
Maneuverability	FF	TBD	TBD	
4. Seakeeping				
Rank Factor		13.02	12.96	-0.5
Roll Period [SEC]		10.01	9.66	-3.5
5. Operability				
RM&A	FFG-7	TBD	TBD	

Note: (1) Sustained speed requirement for sea state 5. Baseline and Variant values given are for calm water. An estimate of the added resistance in waves could be made, but the speed loss should not be enough to drop speed below threshold.

COMPARISON OF BASELINE VS HSLA DECKHOUSE VARIANT (CONT)

	THRESHOLD	BASELINE	VARIANT	DIFF %
<u>Design Margins/Criteria</u>				
1. Margins				
Acq Weight	12.5%	12.5	12.5	
Acq KG	12.5%	12.5	12.5	
Space	0.0%	0.0	0.0	
Acq Electrical	20.0%	20.0	20.0	
S.L. Electrical	20.0%	20.8	20.8	
Propulsion Power	8.0%	8.0	8.0	
Accomodations	10.0%	10.0	10.0	
Strength	2.24 KSI	2.78	2.81	N/S
2. Standards & Practices				
GM_T/B	.08-.12	.097	.103	6.2
FBD_o [FT]	29.6	29.7	29.8	N/S
Prim Stress [KSI]	21.28	18.50	18.47	N/S
Correlation Allow	.0005	.0005	.0005	
<u>Ship Configuration</u>				
1. Gross Characteristics				
LBP [FT]		425.0	425.0	
Beam [FT]		50.00	49.87	-0.3
Draft [FT]		18.77	18.66	-0.6
Depth [FT]		38.00	38.00	
Displacement [LT]		5537.3	5486.5	-0.9
Total Volume [FT^3]		658118	657783	N/S
GM_T [FT]		4.83	5.16	6.8
Disp Lgth Ratio		72.1	71.5	-0.3
Vol Density [LB/FT^3]		18.8	18.7	N/S
2. Powering				
SHP_I		52500	52500	
SHP_E		9859	9794	-0.7
PC_E		0.747	0.747	
SFC_E [LBM/HP-HR]		0.544	0.545	N/S
3. Ship Service				
Propulsion [KW]		267	267	N/S
Average Load [KW]		2669	2668	N/S
Peak Load [KW]		2841	2840	N/S

COMPARISON OF BASELINE VS HSLA DECKHOUSE VARIANT (CONT)

	THRESHOLD	BASELINE	VARIANT	DIFF %
4. Weight				
W_{100} [LT]		1300.7	1261.9	-3.0
W_{150}		156.5	120.2	-23.6
W_{200}		429.6	429.5	N/S
W_{300}		248.4	248.1	N/S
W_{400}		649.6	648.0	N/S
W_{500}		634.6	634.0	N/S
W_{600}		394.0	392.5	N/S
W_{700}		130.0	130.0	
Acq Margin		473.3	468.0	-1.1
Lightship		4260.1	4212.0	-1.1
Loads		1277.2	1274.5	-0.2
Fuel		865.0	862.5	-0.3
Ship Ammo		78.5	78.5	
Aviation		172.5	172.5	
Full Load Weight		5537.3	5486.5	-0.9
Full Load KG [FT]		21.79	21.42	-1.7
Lightship KG		24.7	24.2	-2.0
5. Volume				
Hull [FT^3]		550657	550564	N/S
Deckhouse		107462	107220	N/S
V_1 Mission		148288	148260	N/S
V_2 Human Support		135750	135750	N/S
V_3 Ship Support		196397	196309	N/S
V_4 Mobility		177384	177268	N/S
V_5 Unassigned		299	187	N/S
Total Volume		658118	657783	N/S
6. Manning				
Officer		26	26	
CPO		19	19	
Enlisted		228	228	
Accommodations		301	301	
Cost				
1. R&D Cost (10 yrs)		TBD	TBD	
2. Acquistion Cost				
Lead Ship [$M 1985]		970.1	970.3	N/S
Follow Ship		583.7	583.8	N/S
Average (30 Ships)		559.0	559.0	
3. O&S Cost (30 yrs)		1039.9	1039.6	N/S

COMPARISON OF BASELINE VS HSLA DECKHOUSE VARIANT (CONT)

	THRESHOLD	BASELINE	VARIANT	DIFF %
Risk				
1. Schedule		TBD	TBD	
2. Technical		LOW	MOD-LOW	
3. Cost		TBD	TBD	

COMPARISON OF MAJOR CHARACTERISTICS
BASELINE ASW FRIGATE VERSUS NAVTRUSS VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
<u>Ship Performance</u>				
1. Combat System				
Capacity				
Payload [LT]	675.0	675.0	675.0	
Area [FT^2]	16254	16254	16254	
Effectiveness				
Arrangeability		BLV	Same	
2. Survivability				
Signatures				
IR	DDG-51	TBD	TBD	
RCS	DDG-51	TBD	TBD	
Noise	DD-963	TBD	TBD	
Visual	DD-963	TBD	TBD	
Protection				
Blast	3 PSI	3 PSI	3 PSI	
Frag	LV II	LV II	LV II	
NBC	P-CPS	P-CPS	P-CPS	
Shock	.3 KSF	.3 KSF	.3 KSF	
3. Mobility(1)				
V_S [KT]	24.0	27.95	28.05	0.4
V_E [KT]	20.0	20.0	20.0	
Range [NM]	4500	4500	4500	
Maneuverability	FF	TBD	TBD	
4. Seakeeping				
Rank Factor		13.02	12.92	-0.8
Roll Period [SEC]		10.01	9.39	-9.4
5. Operability				
RM&A	FFG-7	TBD	TBD	

Note: (1) Sustained speed requirement for sea state 5. Baseline and Variant values given are for calm water. An estimate of the added resistance in waves could be made, but the speed loss should not be enough to drop speed below threshold.

COMPARISON OF BASELINE VS NAVTRUSS VARIANT (CONT)

	THRESHOLD	BASELINE	VARIANT	DIFF %
Design Margins/Criteria				
1. Margins				
Acq Weight	12.5%	12.5	12.5	
Acq KG	12.5%	12.5	12.5	
Space	0.0%	0.0	0.0	
Acq Electrical	20.0%	20.0	20.0	
S.L. Electrical	20.0%	20.8	20.9	N/S
Propulsion Power	8.0%	8.0	8.0	
Accomodations	10.0%	10.0	10.0	
Strength	2.24 KSI	2.78	2.86	2.9
2. Standards & Practices				
GM_T/B	.08-.12	.097	.109	12.4
FBD_o [FT]	29.6	29.7	29.9	N/S
Prim Stress [KSI]	21.28	18.50	18.42	N/S
Correlation Allow	.0005	.0005	.0005	
Ship Configuration				
1. Gross Characteristics				
LBP [FT]		425.0	425.0	
Beam [FT]		50.00	49.75	-0.5
Draft [FT]		18.77	18.56	-1.1
Depth [FT]		38.00	38.00	
Displacement [LT]		5537.3	5445.3	-1.7
Total Volume [FT^3]		658118	657539	N/S
GM_T [FT]		4.83	5.43	12.4
Disp Length Ratio		72.1	70.9	-1.7
Vol Density [LB/FT^3]		18.8	18.6	-1.1
2. Powering				
SHP_I		52500	52500	
SHP_E		9859	9748	-1.1
PC_E		0.747	0.747	
SFC_E [LBM/HP-HR]		0.544	0.546	N/S
3. Ship Service				
Propulsion [KW]		267	267	N/S
Average Load [KW]		2669	2666	N/S
Peak Load [KW]		2841	2838	N/S

COMPARISON OF BASELINE VS NAVTRUSS VARIANT (CONT)

	THRESHOLD	BASELINE	VARIANT	DIFF %
4. Weight				
W_{100} [LT]		1300.7	1227.9	-5.6
W_{150}		156.5	88.9	-43.2
W_{200}		429.6	429.5	N/S
W_{300}		248.4	247.9	N/S
W_{400}		649.6	647.9	N/S
W_{500}		634.6	633.5	N/S
W_{600}		394.0	392.4	N/S
W_{700}		130.0	130.0	
Acq Margin		473.3	463.6	-2.0
Lightship		4260.1	4172.0	-2.1
Loads		1277.2	1272.6	-0.4
Fuel		865.0	860.6	-0.5
Ship Ammo		78.5	78.5	
Aviation		172.5	172.5	
Full Load Weight		5537.3	5445.3	-1.7
Full Load KG [FT]		21.79	21.09	-3.2
Lightship KG		24.7	23.8	-3.6
5. Volume				
Hull [FT^3]		550657	550555	N/S
Deckhouse		107462	106983	N/S
V_1 Mission		148288	148250	N/S
V_2 Human Support		135750	135750	
V_3 Ship Support		196397	196240	N/S
V_4 Mobility		177384	177186	N/S
V_5 Unassigned		299	113	N/S
Total Volume		658118	657539	N/S
6. Manning				
Officer		26	26	
CPO		19	19	
Enlisted		228	228	
Accommodations		301	301	
<u>Cost</u>				
1. R&D Cost (10 yrs)		TBD	TBD	
2. Acquistion Cost				
Lead Ship [$M 1985]		970.1	986.8	1.7
Follow Ship		583.7	591.0	1.3
Average (30 Ships)		559.0	565.7	1.2
3. O&S Cost (30 yrs)		1039.9	1042.6	0.3

COMPARISON OF BASELINE VS NAVTRUSS VARIANT (CONT)

	THRESHOLD	BASELINE	VARIANT	DIFF %
Risk				
1. Schedule		TBD	TBD	
2. Technical		LOW	MOD	
3. Cost		TBD	TBD	

COMPARISON OF MAJOR CHARACTERISTICS
BASELINE ASW FRIGATE VERSUS IRGT MAIN ENGINE VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
<u>Ship Performance</u>				
1. Combat System				
Capacity				
Payload [LT]	675.0	675.0	675.0	
Area [FT^2]	16254	16254	16254	
Effectiveness				
Arrangeability		BLV	Degraded	
2. Survivability				
Signatures				
IR	DDG-51	TBD	Improved	
RCS	DDG-51	TBD	TBD	
Noise	DD-963	TBD	TBD	
Visual	DD-963	TBD	TBD	
Protection				
Blast	3 PSI	3 PSI	3 PSI	
Frag	LV II	LV II	LV II	
NBC	P-CPS	P-CPS	P-CPS	
Shock	.3 KSF	.3 KSF	.3 KSF	
3. Mobility(1)				
V_B [KT]	24.0	27.95	27.96	N/S
V_E [KT]	20.0	20.0	20.0	
Range [NM]	4500	4500	4500	
Maneuverability	FF	TBD	TBD	
4. Seakeeping				
Rank Factor		13.02	12.68	-2.6
Roll Period [SEC]		10.01	10.03	N/S
5. Operability				
RM&A	FFG-7	TBD	TBD	

Note: (1) Sustained speed requirement for sea state 5. Baseline and Variant values given are for calm water. An estimate of the added resistance in waves could be made, but the speed loss should not be enough to drop speed below threshold.

COMPARISON OF BASELINE VS IRGT MAIN ENGINE VARIANT (CONT)

	THRESHOLD	BASELINE	VARIANT	DIFF %
Design Margins/Criteria				
1. Margins				
Acq Weight	12.5%	12.5	12.5	
Acq KG	12.5%	12.5	12.5	
Space	0.0%	0.0	0.0	
Acq Electrical	20.0%	20.0	20.0	
S.L. Electrical	20.0%	20.8	21.5	N/S
Propulsion Power	8.0%	8.0	8.0	
Accomodations	10.0%	10.0	10.0	
Strength	2.24 KSI	2.78	2.77	N/S
2. Standards & Practices				
GM_T/B	.08-.12	.097	.095	N/S
FBD_o [FT]	Note (2)	29.7	29.6	N/S
Prim Stress [KSI]	21.28	18.50	18.51	N/S
Correlation Allow	.0005	.0005	.0005	
Ship Configuration				
1. Gross Characteristics				
LBP [FT]		425.0	420.5	-1.0
Beam [FT]		50.00	50.10	0.2
Draft [FT]		18.77	18.34	-2.3
Depth [FT]		38.00	37.55	-1.2
Displacement [LT]		5537.3	5363.4	-3.1
Total Volume [FT^3]		658118	649785	-1.3
GM_T [FT]		4.83	4.83	
Disp Lgth Ratio		72.1	72.1	
Vol Density [LB/FT^3]		18.8	18.5	-1.6
2. Powering				
SHP_I		52500	52500	
SHP_E		9859	9811	-0.5
PC_E		0.747	0.747	
SFC_E [LBM/HP-HR]		0.544	0.372	-31.6
Fuel Cons [NM/LT]		5.2	6.7	28.9
3. Ship Service				
Propulsion [KW]		267	266	N/S
Average Load [KW]		2669	2654	N/S
Peak Load [KW]		2841	2826	N/S

Note: (2) Minimum Freeboard Requirements
Baseline 29.6 FT
Variant 29.1 FT

COMPARISON OF BASELINE VS IRGT MAIN ENGINE VARIANT (CONT)

	THRESHOLD	BASELINE	VARIANT	DIFF %
4. Weight				
W_{100} [LT]		1300.7	1296.8	N/S
W_{200}		429.6	468.0	8.9
W_{300}		248.4	248.0	N/S
W_{400}		649.6	648.8	N/S
W_{500}		634.6	626.0	-1.4
W_{600}		394.0	391.1	N/S
W_{700}		130.0	130.0	
Acq Margin		473.3	476.1	N/S
Lightship		4260.1	4284.9	0.6
Loads		1277.2	1078.5	-15.6
Fuel		865.0	676.3	-21.8
Ship Ammo		78.5	78.5	
Aviation		172.5	172.5	
Full Load Weight		5537.3	5363.4	-3.1
Full Load KG [FT]		21.79	21.93	0.6
Lightship KG		24.7	24.2	-2.0
5. Volume				
Hull [FT^3]		550657	506632	-8.0
Deckhouse		107462	107621	N/S
V_1 Mission		148288	148245	N/S
V_2 Human Support		135750	135753	N/S
V_3 Ship Support		196397	194711	-0.9
V_4 Mobility		177384	170813	-3.7
$V_{4.3}$ Fuel		43793	35222	-19.6
V_5 Unassigned		299	263	N/S
Total Volume		658118	649785	-1.3
6. Manning				
Officer		26	26	
CPO		19	19	
Enlisted		228	228	
Accommodations		301	301	
Cost				
1. R&D Cost (10 yrs)		TBD	TBD	
2. Acquistion Cost				
Lead Ship [$M 1985]		970.1	980.6	1.1
Follow Ship		583.7	588.3	0.8
Average (30 Ships)		559.0	563.2	0.8
3. O&S Cost (30 yrs)		1039.9	1015.9	-2.3
Energy Cost		115.0	90.1	-21.7

COMPARISON OF BASELINE VS IRGT MAIN ENGINE VARIANT (CONT)

	THRESHOLD	BASELINE	VARIANT	DIFF %
Risk				
1. Schedule		TBD	TBD	
2. Technical		LOW	MOD	
3. Cost		TBD	TBD	

COMPARISON OF MAJOR CHARACTERISTICS
BASELINE ASW FRIGATE VERSUS CONTRAROTATING PROPELLER VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
Ship Performance				
1. Combat System				
Capacity				
Payload [LT]	675.0	675.0	675.0	
Area [FT²]	16254	16254	16254	
Effectiveness				
Arrangeability		BLV	Same	
2. Survivability				
Signatures				
IR	DDG-51	TBD	TBD	
RCS	DDG-51	TBD	TBD	
Noise	DD-963	TBD	TBD	
Visual	DD-963	TBD	TBD	
Protection				
Blast	3 PSI	3 PSI	3 PSI	
Frag	LV II	LV II	LV II	
NBC	P-CPS	P-CPS	P-CPS	
Shock	.3 KSF	.3 KSF	.3 KSF	
3. Mobility(1)				
V_B [KT]	24.0	27.95	28.22	1.0
V_E [KT]	20.0	20.0	20.0	
Range [NM]	4500	4500	4500	
Maneuverability	FF	TBD	TBD	
4. Seakeeping				
Rank Factor		13.02	13.03	N/S
Roll Period [SEC]		10.01	10.08	N/S
5. Operability				
RM&A	FFG-7	TBD	Degraded	

Note: (1) Sustained speed requirement for sea state 5. Baseline and Variant values given are for calm water. An estimate of the added resistance in waves could be made, but the speed loss should not be enough to drop speed below threshold.

COMPARISON OF BASELINE VS CONTRAROTATING PROPELLER VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
Design Margins/Criteria				
1. Margins				
Acq Weight	12.5%	12.5	12.5	
Acq KG	12.5%	12.5	12.5	
Space	0.0%	0.0	0.0	
Acq Electrical	20.0%	20.0	20.0	
S.L. Electrical	20.0%	20.8	20.8	
Propulsion Power	8.0%	8.0	8.0	
Accomodations	10.0%	10.0	10.0	
Strength	2.24 KSI	2.78	2.78	
2. Standards & Practices				
GM_T/B	.08-.12	.097	.095	-1.4
FBD_o [FT]	29.6	29.7	29.7	
Prim Stress [KSI]	Note (2)	18.50	18.50	
Correlation Allow	.0005	.0005	.0005	
Ship Configuration				
1. Gross Characteristics				
LBP [FT]		425.0	425.0	
Beam [FT]		50.00	50.00	
Draft [FT]		18.77	18.75	N/S
Depth [FT]		38.00	38.00	
Displacement [LT]		5537.3	5530.9	-0.1
Total Volume [FT^3]		658118	658118	
GM_T [FT]		4.83	4.76	-1.4
Disp Lgth Ratio		72.1	72.0	N/S
Vol Density [LB/FT^3]		18.8	18.8	
2. Powering				
SHP_I		52500	52500	
SHP_E		9859	9777	-0.8
PC_{DESIGN}		0.718	0.805	12.1
PC_E		0.747	0.800	7.1
SFC_E [LBM/HP-HR]		0.544	0.546	N/S
Prop Eff @ Design		0.750	0.755	0.7
Prop Eff @ Endur		0.780	0.750	-3.9
Tot Drag @ Des [LB]		332218	368749	11.0
Tot Drag @ End		101380	107644	6.2
RPM_{DESIGN}		140.0	140.0	
RPM_E		91.2	89.1	-2.3
Propeller Dia [FT]		16.74	13.99	-16.4
Prop Sys Disp [LT]		38.93	43.83	12.6
Design Cav No.		1.69	1.58	-6.5

COMPARISON OF BASELINE VS CONTRAROTATING PROPELLER VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
3. Ship Service				
Propulsion [KW]		267	267	
Average Load [KW]		2669	2669	
Peak Load [KW]		2841	2841	
4. Weight				
W_{100} [LT]		1300.7	1300.3	N/S
W_{200}		429.6	427.2	N/S
W_{300}		248.4	248.4	
W_{400}		649.6	649.6	
W_{500}		634.6	634.5	N/S
W_{600}		394.0	394.0	
W_{700}		130.0	130.0	
Acq Margin		473.3	473.0	N/S
Lightship		4260.1	4257.0	N/S
Loads		1277.2	1273.9	N/S
Fuel		865.0	861.9	-0.4
Ship Ammo		78.5	78.5	
Aviation		172.5	172.5	
Full Load Weight		5537.3	5530.9	-0.1
Full Load KG [FT]		21.79	21.86	0.3
Lightship KG		24.7	24.7	
5. Volume				
Hull [FT^3]		550657	550657	
Deckhouse		107462	107462	
V_1 Mission		148288	148288	
V_2 Human Support		135750	135750	
V_3 Ship Support		196397	196395	N/S
V_4 Mobility		177384	177245	N/S
V_5 Unassigned		299	441	N/S
Total Volume		658118	658118	
6. Manning				
Officer		26	26	
CPO		19	19	
Enlisted		228	228	
Accommodations		301	301	

COMPARISON OF BASELINE VS CONTRAROTATING PROPELLER VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
Cost				
1. R&D Cost (10 yrs)		TBD	TBD	
2. Acquistion Cost				
Lead Ship [$M 1985]		970.1	989.1	2.0
Follow Ship		583.7	592.0	1.4
Average (30 Ships)		559.0	566.6	1.4
3. O&S Cost (30 yrs)		1039.9	1043.3	0.3
Risk				
1. Schedule		TBD	TBD	
2. Technical		LOW	MOD-HIGH	
3. Cost		TBD	TBD	

COMPARISON OF MAJOR CHARACTERISTICS
BASELINE ASW FRIGATE VERSUS PROPULSION DERIVED SSG VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
<u>Ship Performance</u>				
1. Combat System				
Capacity				
Payload [LT]	675.0	675.0	675.0	
Area [FT^2]	16254	16254	16254	
Effectiveness				
Arrangeability		BLV	Degraded	
2. Survivability				
Signatures				
IR	DDG-51	TBD	TBD	
RCS	DDG-51	TBD	TBD	
Noise	DD-963	TBD	TBD	
Visual	DD-963	TBD	TBD	
Protection				
Blast	3 PSI	3 PSI	3 PSI	
Frag	LV II	LV II	LV II	
NBC	P-CPS	P-CPS	P-CPS	
Shock	.3 KSF	.3 KSF	.3 KSF	
3. Mobility[1]				
V_S [KT]	24.0	27.95	27.16	-2.8
V_E [KT]	20.0	20.0	20.0	
Range [NM]	4500	4500	4500	
Maneuverability	FF	TBD	TBD	
4. Seakeeping				
Rank Factor		13.02	12.01	-7.8
Roll Period [SEC]		10.01	9.86	-1.5
5. Operability				
RM&A	FFG-7	TBD	Degraded	

Note: (1) Sustained speed requirement for sea state 5. Baseline and Variant values given are for calm water. An estimate of the added resistance in waves could be made, but the speed loss should not be enough to drop speed below threshold.

COMPARISON OF BASELINE VS PROPULSION DERIVED SSG VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
Design Margins/Criteria				
1. Margins				
Acq Weight	12.5%	12.5	12.5	
Acq KG	12.5%	12.5	12.5	
Space	0.0%	0.0	0.0	
Acq Electrical	20.0%	20.0	20.0	
S.L. Electrical	20.0%	20.8	37.8	81.7
Propulsion Power	8.0%	8.0	8.0	
Accomodations	10.0%	10.0	10.0	
Strength	2.24 KSI	2.78	3.03	9.0
2. Standards & Practices				
GM_T/B	.08-.12	.097	.095	N/S
FBD_o [FT]	Note (2)	29.7	29.1	-2.0
Prim Stress [KSI]	21.28	18.50	18.25	-1.4
Correlation Allow	.0005	.0005	.0005	
Ship Configuration				
1. Gross Characteristics				
LBP [FT]		425.0	415.0	-2.4
Beam [FT]		50.00	49.30	-1.4
Draft [FT]		18.77	17.97	-4.3
Depth [FT]		38.00	37.00	-2.6
Displacement [LT]		5537.3	5104.5	-7.8
Total Volume [FT^3]		658118	626785	-4.8
GM_T [FT]		4.83	4.84	N/S
Disp Lgth Ratio		72.1	71.4	-1.0
Vol Density [LB/FT^3]		18.8	18.2	-3.2
2. Powering				
SHP_I		52500	52500	
SHP_E		9859	13181	33.7
PC_E		0.747	0.747	
SFC_E [LBM/HP-HR]		0.544	0.494	-9.2
Fuel Cons [NM/LT]		5.2	6.3	21.1

Note: (2) Minimum Freeboard Requirements
Baseline 29.6 FT
Variant 28.6 FT

COMPARISON OF BASELINE VS PROPULSION DERIVED SSG VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
3. Ship Service				
Propulsion [KW]		267	266	N/S
Average Load [KW]		2669	2622	-1.8
Peak Load [KW]		2841	2794	-1.7
Total Installed KW		6000	7500	25.0
S.L. Growth [KW]		641	1147	78.9
No. Generators	3	4	3	-25.0
Gen Rating [KW]		1500	2500	66.7
4. Weight				
W_{100} [LT]		1300.7	1218.3	-6.3
W_{200}		429.6	405.4	-5.6
W_{300}		248.4	169.6	-31.7
W_{400}		649.6	646.7	N/S
W_{500}		634.6	594.0	-6.4
W_{600}		394.0	383.2	-2.7
W_{700}		130.0	130.0	
Acq Margin		473.3	443.4	-6.3
Lightship		4260.1	3990.6	-6.3
Loads		1277.2	1113.9	-12.8
Fuel		865.0	710.5	-18.0
Ship Ammo		78.5	78.5	
Aviation		172.5	172.5	
Full Load Weight		5537.3	5104.5	-7.8
Full Load KG [FT]		21.79	21.54	-1.1
Lightship KG		24.7	24.1	-2.4
5. Volume				
Hull [FT^3]		550657	520504	-5.5
Deckhouse		107462	106281	-1.1
V_1 Mission		148288	147954	N/S
V_2 Human Support		135750	135750	
V_3 Ship Support		196397	172186	-12.3
V_4 Mobility		177384	170367	-4.0
V_5 Unassigned		299	508	N/S
Total Volume		658118	626785	-4.8
6. Manning				
Officer		26	26	
CPO		19	19	
Enlisted		228	228	
Accommodations		301	301	

COMPARISON OF BASELINE VS PROPULSION DERIVED SSG VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
Cost				
1. R&D Cost (10 yrs)		TBD	TBD	
2. Acquistion Cost				
Lead Ship [$M 1985]		970.1	957.6	-1.3
Follow Ship		583.7	578.2	-0.9
Average (30 Ships)		559.0	553.9	-0.9
3. O&S Cost (30 yrs)		1039.9	1016.1	-2.3
Energy Cost		115.0	94.6	-17.7
Risk				
1. Schedule		TBD	TBD	
2. Technical		LOW	MOD-HIGH	
3. Cost		TBD	TBD	

COMPARISON OF MAJOR CHARACTERISTICS
BASELINE ASW FRIGATE VERSUS ROTARY ENGINE SSG VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
Ship Performance				
1. Combat System				
Capacity				
Payload [LT]	675.0	675.0	675.0	
Area [FT^2]	16254	16254	16254	
Effectiveness				
Arrangeability		BLV	Degraded	
2. Survivability				
Signatures				
IR	DDG-51	TBD	TBD	
RCS	DDG-51	TBD	TBD	
Noise	DD-963	TBD	TBD	
Visual	DD-963	TBD	TBD	
Protection				
Blast	3 PSI	3 PSI	3 PSI	
Frag	LV II	LV II	LV II	
NBC	P-CPS	P-CPS	P-CPS	
Shock	.3 KSF	.3 KSF	.3 KSF	
3. Mobility(1)				
V_B [KT]	24.0	27.95	27.97	N/S
V_E [KT]	20.0	20.0	20.0	
Range [NM]	4500	4500	4500	
Maneuverability	FF	TBD	TBD	
4. Seakeeping				
Rank Factor		13.02	12.67	-2.7
Roll Period [SEC]		10.01	9.98	N/S
5. Operability				
RM&A	FFG-7	TBD	TBD	

Note: (1) Sustained speed requirement for sea state 5. Baseline and Variant values given are for calm water. An estimate of the added resistance in waves could be made, but the speed loss should not be enough to drop speed below threshold.

COMPARISON OF BASELINE VS ROTARY ENGINE SSG VARIANT (CONT)

	THRESHOLD	BASELINE	VARIANT	DIFF %
Design Margins/Criteria				
1. Margins				
Acq Weight	12.5%	12.5	12.5	
Acq KG	12.5%	12.5	12.5	
Space	0.0%	0.0	0.0	
Acq Electrical	20.0%	20.0	20.0	
S.L. Electrical	20.0%	20.8	21.5	N/S
Propulsion Power	8.0%	8.0	8.0	
Accomodations	10.0%	10.0	10.0	
Strength	2.24 KSI	2.78	2.81	N/S
2. Standards & Practices				
GM_T/B	.08-.12	.097	.097	
FBD_o [FT]	Note (2)	29.7	29.7	
Prim Stress [KSI]	21.28	18.50	18.47	N/S
Correlation Allow	.0005	.0005	.0005	
Ship Configuration				
1. Gross Characteristics				
LBP [FT]		425.0	421.0	-0.9
Beam [FT]		50.00	49.92	N/S
Draft [FT]		18.77	18.43	-1.8
Depth [FT]		38.00	37.65	-0.9
Displacement [LT]		5537.3	5379.7	-2.9
Total Volume [FT^3]		658118	649412	-1.3
GM_T [FT]		4.83	4.85	N/S
Disp Lgth Ratio		72.1	72.1	
Vol Density [LB/FT^3]		18.8	18.6	-1.5
2. Powering				
SHP_I		52500	52500	
SHP_E		9859	9802	-0.6
PC_E		0.747	0.747	
SFC_E [LBM/HP-HR]		0.544	0.545	N/S
Fuel Cons [NM/LT]		5.2	6.3	21.1
3. Ship Service				
Propulsion [KW]		267	266	N/S
Average Load [KW]		2669	2654	N/S
Peak Load [KW]		2841	2826	N/S

Note: (2) Minimum Freeboard Requirements
Baseline 29.6 FT
Variant 29.0 FT

COMPARISON OF BASELINE VS ROTARY ENGINE SSG VARIANT (CONT)

	THRESHOLD	BASELINE	VARIANT	DIFF %
4. Weight				
W_{100} [LT]		1300.7	1289.6	-0.9
W_{200}		429.6	428.0	N/S
W_{300}		248.4	251.0	N/S
W_{400}		649.6	648.7	N/S
W_{500}		634.6	623.4	-1.8
W_{600}		394.0	410.1	4.1
W_{700}		130.0	130.0	
Acq Margin		473.3	472.7	N/S
Lightship		4260.1	4254.3	NN/S
Loads		1277.2	1125.4	-11.9
Fuel		865.0	715.7	-17.3
Ship Ammo		78.5	78.5	
Aviation		172.5	172.5	
Full Load Weight		5537.3	5379.7	-2.9
Full Load KG [FT]		21.79	21.79	
Lightship KG		24.7	24.2	-2.0
5. Volume				
Hull [FT^3]		550657	541926	-1.6
Deckhouse		107462	107486	N/S
V_1 Mission		148288	148215	N/S
V_2 Human Support		135750	135747	N/S
V_3 Ship Support		196397	194690	-0.9
V_4 Mobility		177384	170602	-3.8
V_5 Unassigned		299	158	N/S
Total Volume		658118	649412	-1.3
6. Manning				
Officer		26	26	
CPO		19	19	
Enlisted		228	228	
Accommodations		301	301	
Cost				
1. R&D Cost (10 yrs)		TBD	TBD	
2. Acquistion Cost				
Lead Ship [$M 1985]		970.1	964.2	-0.6
Follow Ship		583.7	581.1	-0.4
Average (30 Ships)		559.0	556.6	-0.4
3. O&S Cost (30 yrs)		1039.9	1018.1	-2.1
Energy Cost		115.0	95.3	-17.1

COMPARISON OF BASELINE VS ROTARY ENGINE SSG VARIANT (CONT)

	THRESHOLD	BASELINE	VARIANT	DIFF %
Risk				
1. Schedule		TBD	TBD	
2. Technical		LOW	MOD	
3. Cost		TBD	TBD	

COMPARISON OF MAJOR CHARACTERISTICS
BASELINE ASW FRIGATE VERSUS COMPOSITE MAST & LADDER VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
<u>Ship Performance</u>				
1. Combat System[1]				
Capacity				
Payload [LT]	675.0	675.0	675.0	
Area [FT^2]	16254	16254	16254	
Effectiveness				
Arrangeability		BLV	Same	
2. Survivability				
Signatures				
IR	DDG-51	TBD	TBD	
RCS	DDG-51	TBD	TBD	
Noise	DD-963	TBD	TBD	
Visual	DD-963	TBD	TBD	
Protection				
Blast	3 PSI	3 PSI	3 PSI	
Frag	LV II	LV II	LV II	
NBC	P-CPS	P-CPS	P-CPS	
Shock	.3 KSF	.3 KSF	.3 KSF	
3. Mobility[2]				
V_S [KT]	24.0	27.95	27.96	N/S
V_E [KT]	20.0	20.0	20.0	
Range [NM]	4500	4500	4500	
Maneuverability	FF	TBD	TBD	
4. Seakeeping				
Rank Factor		13.02	13.02	
Roll Period [SEC]		10.01	9.90	-1.1
5. Operability				
RM&A	FFG-7	TBD	TBD	

Notes:

(1) Composites may offer improved EMI characteristics.

(2) Sustained speed requirement for sea state 5. Baseline and Variant values given are for calm water. An estimate of the added resistance in waves could be made, but the speed loss should not be enough to drop speed below threshold.

COMPARISON OF BASELINE VS COMPOSITE MAST & LADDER VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
Design Margins/Criteria				
1. Margins				
Acq Weight	12.5%	12.5	12.5	
Acq KG	12.5%	12.5	12.5	
Space	0.0%	0.0	0.0	
Acq Electrical	20.0%	20.0	20.0	
S.L. Electrical	20.0%	20.8	20.8	
Propulsion Power	8.0%	8.0	8.0	
Accomodations	10.0%	10.0	10.0	
Strength	2.24 KSI	2.78	2.78	
2. Standards & Practices				
GM_T/B	.08-.12	.097	.099	2.3
FBD_O [FT]	29.6	29.7	29.7	
Prim Stress [KSI]		18.50	18.50	
Correlation Allow	.0005	.0005	.0005	
Ship Configuration				
1. Gross Characteristics				
LBP [FT]		425.0	425.0	
Beam [FT]		50.00	50.00	
Draft [FT]		18.77	18.76	N/S
Depth [FT]		38.00	38.00	
Displacement [LT]		5537.3	5530.1	-0.1
Total Volume [FT^3]		658118	658118	
GM_T [FT]		4.83	4.94	2.3
Disp Lgth Ratio		72.1	72.0	N/S
Vol Density [LB/FT^3]		18.8	18.8	
2. Powering				
SHP_I		52500	52500	
SHP_E		9859	9848	N/S
PC_E		0.747	0.747	
SFC_E [LBM/HP-HR]		0.544	0.544	
3. Ship Service				
Propulsion [KW]		267	267	
Average Load [KW]		2669	2669	
Peak Load [KW]		2841	2841	

COMPARISON OF BASELINE VS COMPOSITE MAST & LADDER VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
4. Weight				
W_{100} [LT]		1300.7	1295.9	-0.4
W_{200}		429.6	429.5	N/S
W_{300}		248.4	248.4	
W_{400}		649.6	649.6	
W_{500}		634.6	634.6	
W_{600}		394.0	392.8	
W_{700}		130.0	130.0	
Acq Margin		473.3	472.6	N/S
Lightship		4260.1	4253.3	-0.2
Loads		1277.2	1276.8	N/S
Fuel		865.0	864.6	N/S
Ship Ammo		78.5	78.5	
Aviation		172.5	172.5	
Full Load Weight		5537.3	5530.1	-0.1
Full Load KG [FT]		21.79	21.70	-0.4
Lightship KG		24.7	24.5	-0.8
5. Volume				
Hull [FT^3]		550657	550657	
Deckhouse		107462	107462	
V_1 Mission		148288	148288	
V_2 Human Support		135750	135750	
V_3 Ship Support		196397	196394	N/S
V_4 Mobility		177384	177366	N/S
V_5 Unassigned		299	326	N/S
Total Volume		658118	658118	
6. Manning				
Officer		26	26	
CPO		19	19	
Enlisted		228	228	
Accommodations		301	301	
Cost				
1. R&D Cost (10 yrs)		TBD	TBD	
2. Acquistion Cost				
Lead Ship [$M 1985]		970.1	970.2	N/S
Follow Ship		583.7	583.7	
Average (30 Ships)		559.0	559.0	
3. O&S Cost (30 yrs)		1039.9	1039.9	
Risk				
1. Schedule		TBD	TBD	
2. Technical		LOW	MOD-LOW	
3. Cost		TBD	TBD	

COMPARISON OF MAJOR CHARACTERISTICS
BASELINE ASW FRIGATE VERSUS INTEGRATED TECHNOLOGY VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
Ship Performance				
1. Combat System				
Capacity				
Payload [LT]	675.0	675.0	675.0	
Area [FT^2]	16254	16254	16254	
Effectiveness				
Arrangeability		BLV	Degraded	
2. Survivability				
Signatures				
IR	DDG-51	TBD	TBD	
RCS	DDG-51	TBD	TBD	
Noise	DD-963	TBD	TBD	
Visual	DD-963	TBD	TBD	
Protection				
Blast	3 PSI	3 PSI	3 PSI	
Frag	LV II	LV II	LV II	
NBC	P-CPS	P-CPS	P-CPS	
Shock	.3 KSF	.3 KSF	.3 KSF	
3. Mobility(1)				
V_B [KT]	24.0	27.95	27.49	-1.8
V_E [KT]	20.0	20.0	20.0	
Range [NM]	4500	4500	4500	
Maneuverability	FF	TBD	TBD	
4. Seakeeping				
Rank Factor		13.02	12.21	-6.2
Roll Period [SEC]		10.01	9.72	-2.9
5. Operability				
RM&A	FFG-7	TBD	Degraded	

Note: (1) Sustained speed requirement for sea state 5. Baseline and Variant values given are for calm water. An estimate of the added resistance in waves could be made, but the speed loss should not be enough to drop speed below threshold.

COMPARISON OF BASELINE VS INTEGRATED TECHNOLOGY VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
Design Margins/Criteria				
1. Margins				
Acq Weight	12.5%	12.5	12.5	
Acq KG	12.5%	12.5	12.5	
Space	0.0%	0.0	0.0	
Acq Electrical	20.0%	20.0	20.0	
S.L. Electrical	20.0%	20.8	37.8	81.7
Propulsion Power	8.0%	8.0	8.0	
Accomodations	10.0%	10.0	10.0	
Strength	2.24 KSI	2.78	2.51	-9.7
2. Standards & Practices				
GM_T/B	.08-.12	.097	.095	N/S
FBD_o [FT]	Note (2)	29.7	29.3	-1.3
Prim Stress [KSI]	21.28	18.50	18.77	1.5
Correlation Allow	.0005	.0005	.0005	
Ship Configuration				
1. Gross Characteristics				
LBP [FT]		425.0	421.0	-0.9
Beam [FT]		50.00	48.52	-3.0
Draft [FT]		18.77	17.82	-4.5
Depth [FT]		38.00	37.00	-2.6
Displacement [LT]		5537.3	5048.2	-8.8
Total Volume [FT^3]		658118	625923	-4.9
GM_T [FT]		4.83	4.82	N/S
Disp Lgth Ratio		72.1	67.7	-6.1
Vol Density [LB/FT^3]		18.8	18.1	-3.7
2. Powering				
SHP_I		52500	52500	
SHP_E		9859	12927	31.1
PC_E		0.747	0.747	
SFC_E [LBM/HP-HR]		0.544	0.497	-8.6
Fuel Cons [NM/LT]		5.2	6.4	23.1

Note: (2) Minimum Freeboard Requirements
Baseline 29.6 FT
Variant 29.3 FT

COMPARISON OF BASELINE VS INTEGRATED TECHNOLOGY VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
3. Ship Service				
Propulsion [KW]		267	266	N/S
Average Load [KW]		2669	2622	-1.8
Peak Load [KW]		2841	2795	-1.6
Total Installed KW		6000	7500	25.0
S.L. Growth [KW]		641	1147	78.9
No. Generators	3	4	3	-25.0
Gen Rating [KW]		1500	2500	66.7
4. Weight				
W_{100} [LT]		1300.7	1180.1	-9.3
W_{150}		156.5	116.0	-25.9
W_{200}		429.6	407.4	-5.2
W_{300}		248.4	167.3	-32.6
W_{400}		649.6	645.3	N/S
W_{500}		634.6	594.2	-6.4
W_{600}		394.0	381.6	-3.1
W_{700}		130.0	130.0	
Acq Margin		473.3	438.2	-7.4
Lightship		4260.1	3943.9	-7.4
Loads		1277.2	1104.2	-13.6
Fuel		865.0	701.4	-18.9
Ship Ammo		78.5	78.5	
Aviation		172.5	172.5	
Full Load Weight		5537.3	5048.2	-8.8
Full Load KG [FT]		21.79	21.13	-3.0
Lightship KG		24.7	23.5	-4.9
5. Volume				
Hull [FT^3]		550657	521583	-5.3
Deckhouse		107462	104341	-2.9
V_1 Mission		148288	147863	N/S
V_2 Human Support		135750	135752	N/S
V_3 Ship Support		196397	172108	-12.4
V_4 Mobility		177384	169950	-4.2
V_5 Unassigned		299	249	N/S
Total Volume		658118	625923	-4.9
6. Manning				
Officer		26	26	
CPO		19	19	
Enlisted		228	228	
Accommodations		301	301	

COMPARISON OF BASELINE VS INTEGRATED TECHNOLOGY VARIANT

	THRESHOLD	BASELINE	VARIANT	DIFF %
Cost				
1. R&D Cost (10 yrs)		TBD	TBD	
2. Acquistion Cost				
Lead Ship [$M 1985]		970.1	957.3	-1.3
Follow Ship		583.7	578.1	-1.0
Average (30 Ships)		559.0	553.8	-0.9
3. O&S Cost (30 yrs)		1039.9	1014.7	-2.4
Fuel Cost		115.0	94.2	-18.1
Risk				
1. Schedule		TBD	TBD	
2. Technical		LOW	MOD-HIGH	
3. Cost		TBD	TBD	

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